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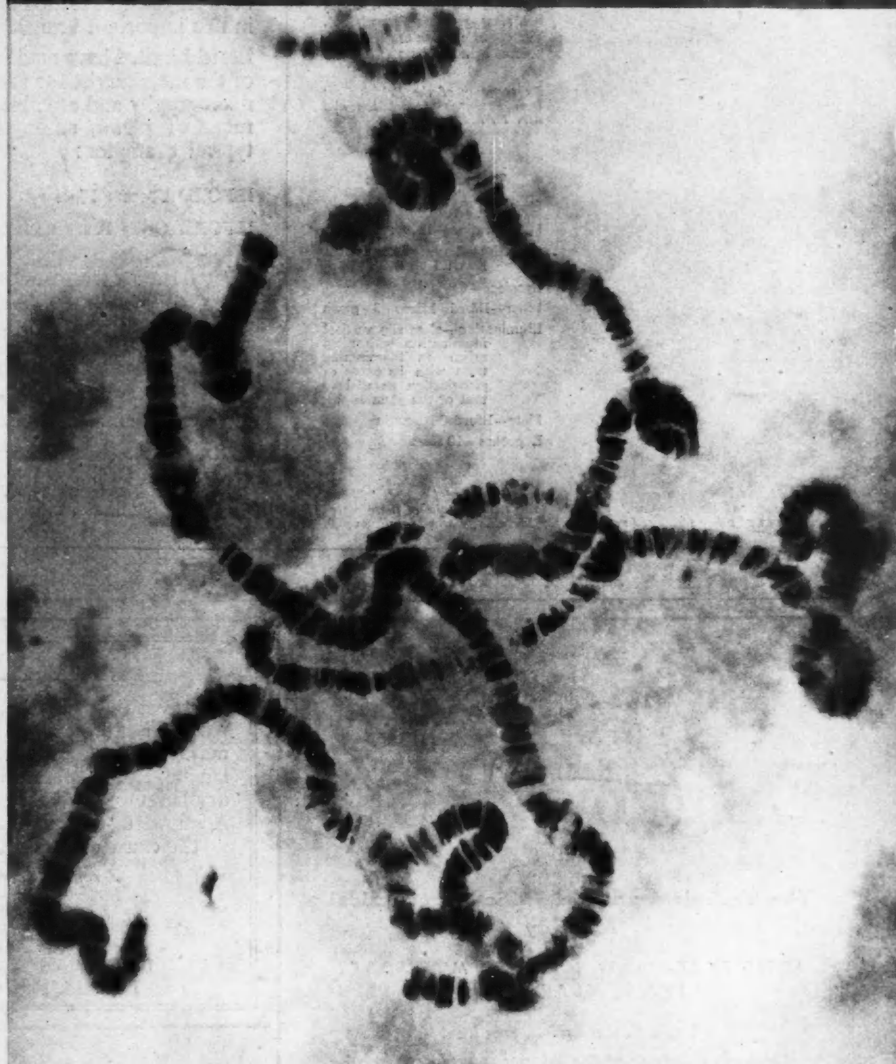

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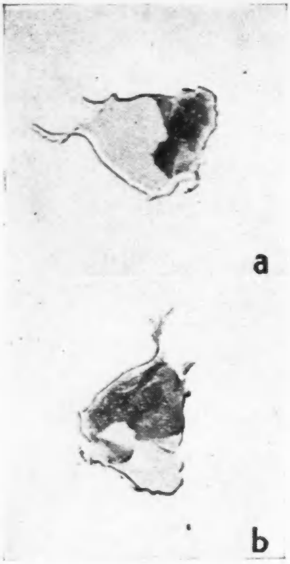
PHOTOMICROGRAPHY for METALLURGISTS



Showing pleochroic iron telluride in a sample of white cast iron under plane polarised light. B shows the same spot as A but after rotating through 90°. The crystals which are dark in A become light in B and vice versa.

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The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE DIRECTION OF DAVID S. EVANS

The Motivation of Research

Ask a scientist why science advances. If the inquiry is addressed to an industrial scientist, he will say that he advances his own branch of science because he is paid to do so by his firm, and that their conception of the usefulness of science is for the furtherance of their own interests. If this industrial scientist has done a little thinking he will always be feeling the impulse to go beyond this narrow direct motivation and, taking a very much broader view, will try to mould his work in order to gain the opportunity of contributing something to the extension of fundamental knowledge. If his firm has also done some thinking they will not discourage this tendency, but will act on their realisation of the elementary fact that it is, in the end, the extension of fundamental science which opens up new and profitable lines of advance.

Put the same question to a scientist in a university, especially one who has held a comfortable post for a number of years, and he will say that science advances because there are workers who have a natural keen curiosity about the workings of nature and that this enthusiastic desire for knowledge is the factor which overcomes obstacles.

Put the question to a scientist who is interested in the history of his subject, especially in relation to the general course of contemporary history, and he will give a rather sophisticated answer describing the interaction of general social needs with scientific development.

All these answers are true, but they have shared truth between them in different proportions at various times and in various sciences. In the past, the study of the social relations of science has turned up many cases in which there was a general overall controlling influence exercised by social needs. The problems of navigation, of the steam engine and other prime movers and locomotives were in the air. So much attention was directed to their solution that the answers were certain to be found sooner or later. What is more, this motivation must have been largely unconscious, the thoughts of the investigators being turned to them by the general public discussions which were proceeding.

In some of its most fruitful periods it is easy to see the strictly practical economic and social factors which played so large a part in conditioning the directions of advance. These factors range all the way from the crude demands of war, which may be met by a deliberate organisation of scientific research, to the much subtler cases when social conditions have, as it were, exercised no more than a statistical direction of random developments. It is perfectly correct that the first analyses of the social relations of science should have been made along these lines, especially when they are intended for the consumption of a general public fed on the legend of the isolated, inwardly motivated worker remote from ordinary life.

It is unfortunately always thus when controversial matters are in question. In order to bring out one side of a question which has not previously been considered there must be a concentration on one aspect and perhaps consequent accusations that this is the only aspect which is recognised. We have now reached a stage when a more truly scientific discussion of the social relationships of science has become possible. The public at large no longer looks on the scientist as a distant figure occupied with the minutiæ of esoteric and irrelevant problems, but as an important ally of social advance.

No one who has maintained this view will have fallen into the error of denying the importance of the scientist's enthusiasm for his own work, or will have asserted that crude social conditioning represents the whole story.

The case has in fact been won: the operation of social causes in determining scientific advance has been amply demonstrated by masterly surveys of the history of scientific progress. Now that the opposition to this view has become negligible the danger arises of alienating even former allies through a neglect of other forces involved in scientific development. It may indeed still be necessary to stress the utilitarian aspect when writing for the general public, but a need is arising for something a little more subtle for a scientific audience.

The general lines of social motivation have been sketched in over the whole history of science, and there is no need to withdraw one word of what has been written by the abler thinkers in this field. There is equally no need to

Versatile Professor Haldane has entered the astronomers' domain by offering a new explanation of the origin of planets. How many astronomers could return the visit?

increase the bulk of what has been written except for general non-specialist consumption. At the moment there is a danger that the subject may stand still and that it will continue to repeat the thoroughly admirable contents of *The Social Function of Science* to those who already accept and value its discussions.

In the post-war world there will be time for new developments in the theory of the social relations of science, and it is interesting to speculate what direction these will take. Since the essential correctness of a broad overall economic motivation has been established, there will be no need to withdraw what has been said already, but further additions must be made. It is true that in the period of greatest development of, for example, navigational technique, astronomy advanced rapidly, but it continued to advance after social needs had changed and were having their most direct influence on other subjects. So we are left with this definite problem: to discuss the progress of particular subjects during periods when the spotlight of social need is directed elsewhere.

Here we must be concerned with many factors, one of them definitely economic, namely the complexion of finance which has been carried over from the period of definite social conditioning. This carry-over provides opportunity but it does not determine direction. The direction of advance will depend first of all on the purely scientific evolution which has taken place since the period of solving practical problems, and secondly on interactions with other branches of science which may themselves be under the influence of social causes. We may enquire how often it has happened that entirely new trains of thought and development have been started during such interim periods and how long an interval there has been before such new developments have been recognised as of practical value. All this is included in the remark, often made rather casually, "Of course scientific development has a tremendous momentum and continues long after the exciting social cause is removed". Such an answer is too superficial for modern times, and it is not too much to ask now that after the war someone should devote his attention to these problems. We must in fact try to encourage a less polemical and more detailed approach and the answers must describe in more satisfactory detail to what extent the personal enthusiasm of scientists, which is one—but only one—of the factors involved in this notion of momentum of scientific advance, has played a part, and whether it is possible to make general statements from the study of the progress of particular sciences.

The other aspect which must be considered in more detail is the mechanism by which social conditioning finds its expression in the activity of scientists. We must not fall into the pit of anecdotage, and demonstrate our own historical dotage by coming down to the level of the story of Newton and the apple and such like romances, but this question merits a fuller discussion than it has received. In particular there have been great problems which could be solved only by minds of a certain calibre and it would have a considerable effect of a thoroughly practical value if assertions, such as the one that there is born only one potential good physicist per million of population, could be refuted or supported. In fact we may think of social needs crying out to be met: now we would like to know the probability of the emergence of an intellect of sufficient power to meet these needs.

All this is a plea for the setting of new levels of evidence in the study of the social relations of science lest the accusation that conclusions are being formed on insufficient evidence be made good. The problems suggested are concerned with the historical side rather than with the problem of applying knowledge of the past to future conditions. It may be argued that this is a deviation to less important tasks of the few intellects who have added to this subject or who now seem capable of advancing it. It may be regarded as a plea for the study of history, when the better part would be for a plea for the making of history.

The writer does not think so: there is a danger that those who are best fitted to advance science and whose words will carry most weight in a scientific world will see the inadequacy on certain points of the arguments which have been advanced so far. Their support is likely to be gained only by discussions which are intellectually convincing judged by their own scientific standards: they will feel the need of getting down to cases as distinct from a general survey of the historical field, and it is at least arguable that eventual progress will be more rapid if this is done.

Universalists in Science

In a recent issue of *Nature* there appeared a short article by Professor J. B. S. Haldane deducing from Professor E. A. Milne's theory of kinematical relativity a possible mechanism for the origin of the planets of the solar system. In brief, it is that in the distant past photons of an almost fantastically high energy must have been available, and that such a photon, being absorbed by the sun, was sufficient to produce a disintegration. The suggestion is welcomed by Professor Milne, who acknowledges its validity and the "rapier-like speed" of Haldane's mind. This is praise indeed from one, who, as Damon Runyon might say, is no crow himself.

Perhaps even more interesting than the suggestion itself is the fact that Haldane should have made it. How many astronomers could tell Haldane a thing or two about genetics? Probably none, and we are led to wonder how often it has happened that a scientist in one branch has been able to make a capital suggestion in a totally different field.

We must of course restrict ourselves to comparatively modern times, since, if we go back to the time of the foundation of the Royal Society or earlier we find that science was then so unified that specialisation had not developed very far. Even in those far off times we find men remarkable for their versatility, perhaps the most notable being Edmond Halley, who made first-class contributions to the sciences of geomagnetism, meteorology, mathematics and astronomy; he was one of the founders of the science of vital statistics, and was in turn an amateur (but most effective) sea-captain, a professor of geometry and Astronomer Royal. At a later date, versatility in mathematics and physical science had come to have a narrower meaning, so that even Gauss, the Prince of mathematicians, included all his work within a wide field of cognate subjects, while at the beginning of this century, Henri Poincaré, described as the last of the universalists, worked in a field rather narrower than that of Gauss and gained his well-merited fame by the depth rather than the range of his work.

These are men who worked in the field of mathematical physics and stayed within it. There are examples of scientists in other fields who have made themselves famous in other branches of learning. There is one instance of professorships of philosophy and chemistry having been held by the same man; Borodin, the Russian musician, was also a chemist; doubtless many more examples could be cited. It may be no more than an erroneous impression but it would seem that such examples of versatility are less common in the sciences which demand a close attention to experimental technique, and relatively more common among workers in fields such as mathematics where, for many workers, the attention is required very intensively for relatively short periods. On the whole, the examples of versatility which we have show a tendency to choose some non-scientific subject as a second string, reserving all the scientific capacity for progress in the branch chosen as a profession.

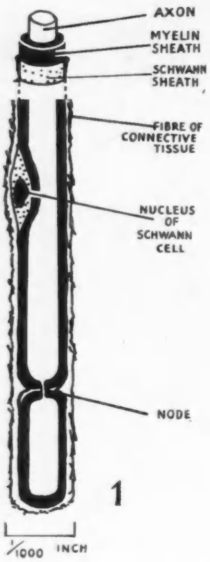
There are, of course, plenty of scientists who can get by in branches of science other than their own when need arises, and plenty who have done extremely good work during this and the last war in the remotest subjects. What is lacking in these cases is the professional quality which distinguishes this idea of Haldane's and which, as far as memory goes, seems to be almost unique in the history of science during the last two centuries.

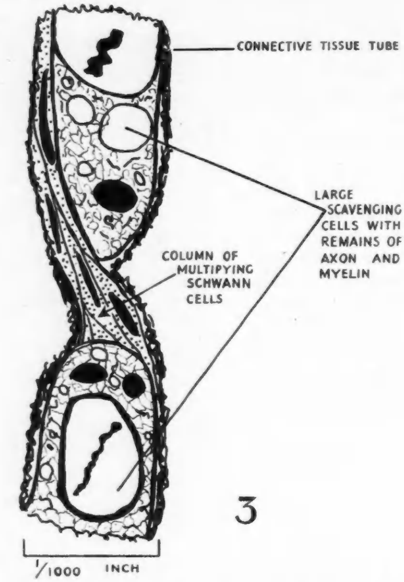
Fig. 2.—Photomicrograph showing cross-section of a small nerve from a rabbit. Each circle is a nerve fibre (× 200 approx.).

How Injured Nerves are Mended

In at least 5% of all war injuries a nerve is severed. Although the extent of the wound may be small and the damage to other tissues not extensive, a nerve injury is a very serious matter for the patient. For when one of the main nerves of the arm or leg is severed, all the muscles supplied by that nerve become totally paralysed, and all the skin which it innervates is rendered totally insensitive. The repair of severed nerves, and the initiation of recovery from paralysis and insensitivity, is one of the major preoccupations of war surgery, and a great deal of research work has been devoted to the particular problems which it raises. A nerve is essentially a bundle of conductors. The latter are of two types. One type, *the motor fibres*, carry electrical messages to muscles and cause them to contract. The other type, *the sensory* fibres, carry messages from the sense organs to the spinal cord and brain. Each fibre is itself a complex unit (Fig. 1), consisting of a central core, or *axon*, which has a viscous semi-fluid consistency and is an extension of a single cell lying, in the case of those fibres which work muscles, in the spinal cord. Around each axon is a complex sheath of a fatty nature—*the myelin sheath*—in which, at intervals, there are gaps called *nodes*. Outside the myelin sheath there is a sheath of cells surrounding each fibre—*the Schwann cells*. And again, outside the Schwann sheath, is a tube composed of connective tissue which encloses the whole fibre.

Considering that a medium-sized nerve in man may contain anything up to 50,000 of these fibres, each with the structure indicated, and varying in size from about $\frac{1}{20000}$ in. to $\frac{1}{1000}$ in. across, it will be seen that a nerve has a fairly complex internal structure. The photograph (Fig. 2) gives a picture of a cross-section of a small rabbit's nerve which contains only a few fibres. Before being





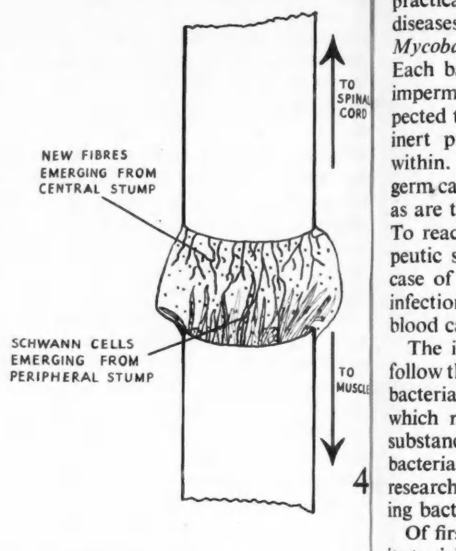


FIG. 1.—Diagram showing the structure of part of a normal nerve fibre. At the top the arrangement of the different layers around the central cylinder or axon is indicated, the layers being shown as they would appear in surface view if it were possible to strip off one layer at a time as one might with an electric cable. The bottom part of the diagram shows the arrangement in optical section FIG. 3.—Part of a degenerating fibre. FIG. 4.—Diagram of an injured nerve regenerating.

photographed this section was coloured by dyes in such a way as to render visible one of the sheaths, the myelin sheath; that of each fibre appears as a black ring in the photograph.

When such a nerve is severed some rather curious changes take place within it. Let us consider first the portion which remains connected with the spinal cord, called by biologists the "central" stump. From this stump the severed axons start to grow out into the gap between the stumps. In the other part of the nerve—the "peripheral" stump—a process occurs called *Wallerian degeneration* after its discoverer, a 19th century biologist. In Wallerian degeneration the axons and myelin sheaths break up and are removed by wandering, scavenging cells which invade the nerve. The connective tissue tubes that enclose the fibres remain, however, and within them the Schwann cells start to multiply (Fig. 3). The final effect of Wallerian degeneration is thus to reduce the nerve to a series of tubes, each of which is kept full by its content of Schwann cells. Schwann cells also move out from the tip of the peripheral stump tandem fashion so that, if the two stumps are brought reasonably near to one another, they can connect up with the central stump. (Fig. 4). If one of the sprouting axons of the central stump comes into contact with one of these Schwann cell columns, it runs along it back into one of the tubes of the peripheral stump. Once confined within a tube the axon continues to run down it to its termination, and thus reconnects with muscle or skin. Thereafter it acquires a new myelin sheath, grows in size, and starts to function once more. When sufficient functioning nerve fibres get back into a muscle, recovery from paralysis occurs; when enough fibres get back into an area of skin, feeling returns.

From the above it would appear that all the surgeon has to do to ensure perfect recovery from a nerve injury is to sew the stumps together, thereby making it possible for a large number of sprouting axons to get back into peripheral tubes. But recent research has shown that the problem is not quite as simple as that. Firstly, it has been discovered that sensory nerve fibres are unable to make functional contact with muscle fibres, while motor fibres cannot connect with sense organs. So it is not sufficient for every fibre from the central stump to be guided merely into one of the peripheral tubes. For perfect recovery, each motor fibre must be led into a tube which leads to a muscle fibre, and each sensory fibre into a tube which leads to a sensory ending. When a nerve is sewn together this does not happen to many of the fibres. There is considerable mixing up of fibres between the two stumps, so that many fibres get lost down the wrong sort of tubes.

Chemotherapy and Tuberculosis

THE introduction into medicine of the sulphonamide drugs, and later penicillin, has demonstrated that many kinds of bacterial infection can be successfully combated by means of chemical agents. Quite naturally hopes have been raised that these or other drugs might be of value in the treatment of tuberculosis. Unfortunately these hopes have not yet been fulfilled—neither penicillin nor sulphonamides attack the tubercle bacillus in the body—but experimental work now in progress does suggest that chemotherapy may in time prove effective in the treatment of this disease, which accounts for one death in every twenty.

The chemotherapy of tuberculosis presents a number of

practical problems which are not found in studying other diseases. The micro-organism which causes tuberculosis, *Mycobacterium tuberculosis*, has certain unusual properties. Each bacterial cell is protected by a waxy coat which is impermeable to many substances. No drug can be expected to attack the organism unless it can penetrate this inert protective coat and reach the living protoplasm within. A further difficulty is that the lesions which the germ causes in the body are not supplied with blood vessels as are the lesions caused by most other types of bacteria. To reach infections of the body as a whole chemotherapeutic substances must be carried by the blood; in the case of tuberculosis the blood stops short of the foci of infection, and so any therapeutic substance carried in the blood can reach the infection only by indirect ways.

The investigations of all new chemotherapeutic agents follow the same general course. The first work is done with bacteria growing in artificial media such as broth, to which may be added blood or other body fluids. If a substance is found to have a pronounced activity against bacteria growing under artificial conditions, then further research will be done to determine its suitability for attacking bacteria in the body.

Of first importance in this respect is a determination of its toxicity. The great majority of antibacterial substances fail on this test because they prove to be as toxic to animal cells as they are to bacteria.

It must also be shown that the proposed drug is not destroyed or rendered inactive by substances normally present in blood and other body fluids. Not until a drug has shown (a) activity against isolated cultures of bacteria in the presence of blood, and (b) a low toxicity to animal cells, is it feasible to test its effect on bacterial infections existing in living animals. In the case of *M. tuberculosis* this early work presents unusual difficulties. This organism is particularly slow in growing so that it may take two or three weeks to see an effect on growth which with other bacteria might be visible in less than 24 hours. Some of the preliminary work can be done with certain non-virulent varieties of the tubercle bacillus but the final tests must be done with the virulent types which actually cause disease, since these may react differently from the non-virulent strains. To protect the research workers elaborate precautions must be taken, and this again slows down the work.

Certain drugs have now been found which pass all the preliminary tests and a small proportion of them have shown promise when examined further and tested against tubercle bacilli which have actually invaded animal tissues. Of these drugs those which have been most closely investigated belong to the class of substances known as sulphones. Promin (a derivative of *p*, *p'*-diaminodiphenylsulphone) has been successfully used by American workers to check the course of experimental tuberculous infections in guinea-pigs. A related substance, promizole, has produced rather better results, being less toxic. It should be remarked, however, that not all workers have been able to reproduce these results in their own laboratories. This is not in any way a reflection on the original workers but rather a demonstration of the fact that small variations in technique may produce very big differences in the final results. Different strains of guinea-pigs vary in their natural resistance to infection, and this is probably an important factor in accounting for the disparity in results. Yet another sulphone, sulphabenamide, contains in its molecule a lipophilic (literally, "fat-loving") fraction which assists the penetration of the waxy covering of *M. tuberculosis*. It has been reported that in preliminary clinical trials five cases of advanced tuberculosis of both lungs treated over ten months gave absence of *M. tuberculosis* from the sputum, and X-ray pictures showed that the lesions had gone.

Feldman, a pioneer of sulphone treatment, and his co-workers in the United States have introduced yet another sulphone (4-2'-diaminophenyl-5'-thiazole-sulphone) similar to promin and have obtained encouraging results. It must be mentioned that the sulphones as a class are rather toxic substances—promin, for example, is liable to cause anæmia—and their general administration requires very careful supervision. At present their main use is in the form of an ointment or jelly for local treatment of tubercular abscesses and sinuses. Even for this their true value has still be to be assessed.

Apart from the sulphones, an antibiotic called streptomycin also shows some promise of being effective against the tubercle bacillus, as well as against a number of other bacteria which do not react to other known chemotherapeutic agents. Streptomycin is a metabolic product of a species of fungus called *Actinomyces griseus*. It has a moderately low toxicity and considerable activity against tubercle bacilli growing in artificial media. In animal experiments it has proved very effective in overcoming various types of bacteria, such as *Pasteurella tularensis*, resistant to other chemotherapeutic agents. In man *P. tularensis* causes tularæmia, a disease similar to Malta Fever.

If chemotherapy does eventually prove an effective method of treating tuberculosis, early diagnosis will be a very important factor in determining its ultimate success. Fortunately present schemes for Mass Radiography should do much to ensure that early diagnosis can be made. Tuberculosis, if unchecked, causes extensive and irreparable mechanical damage to the organs it attacks. If treatment is delayed the patient may be left with permanently impaired functions of a vital organ, such as the lungs, even though the infection itself may be completely overcome. Whatever form treatment takes this is a powerful argument for seeking proper medical advice immediately suspicions are aroused.

In conclusion it must be very strongly emphasised that all the work described in this note is still in the experimental stage. A great deal of it relates to tuberculosis in animals and these commonly differ greatly from Man in their response to bacterial infections. Not until exhaustive clinical work has been done will it be possible to assess the real value of these drugs in treating human tuberculosis. It should be realised, too, that great caution is needed in estimating the true effect of treating human patients, as it is not uncommon for tuberculosis to regress without any treatment at all. For the time being conventional modes of treatment—good food, fresh air and exercise—must be followed and no hope encouraged of immediate prospects of simplified therapy. It is, however, clear that this new line of research holds out considerable promise for the future and it is satisfactory to know that in spite of war-time difficulties it is being vigorously pursued.

The Problem of Priorities

H. W. SINGER, Ph.D.

In the previous article (published in the December issue) I tried to assess the probable size of post-war resources. The conclusion reached was that when the immediate period of post-war readjustment is over a certain expansion of the national income may be looked forward to. This expansion, however, although we shall assume it to be definite and of the order of magnitude of about 20 to 25%, is far from miraculous. The idea that we could produce enough for full abundance and that we are only held back from solving the economic problem by difficulties of distribution or of monetary organisation is a complete myth. The day when we could say that productive capacity outruns social needs is still very far off. The writer of this article will not live to see it, nor will any of his readers.

Let us assume then that some time, about 8 or 10 years after the war, extra resources will be available to the extent of some £1,500,000,000. This figure is suggested on the assumption that post-war prices will be some 35% higher than they were before the war and will be kept fairly stable at that level. This corresponds to Government intentions and declarations.

On this sum of £1,500,000,000, representing a new flow of goods and services to that value, there will converge a number of conflicting claims which in their magnitude are certain to exceed the sum available. It follows, therefore, that these possible claims, most of them already announced from various quarters, cannot all be fulfilled at the same time. Some of them will have to give way to others. This, in a nutshell, is the problem of priorities.

A Common Delusion

At this stage, it is important to clear up a popular and widespread misunderstanding—the idea that there is no need for any special system of priorities because most of the things proposed, such as an extension of social services, "do not really cost anything at all." Are we not just putting money, people ask, from one pocket into the other? After all, if we give extra family allowances or higher old-age pensions, the thing is simply a question of domestic distribution. No extra real resources are being used. Money is taken from some people and given to other people. The whole thing is simple "transfer." £ s. d. is a "meaningless symbol" whenever the question of social improvement comes up. In such and similar familiar grooves runs the popular argument of the costlessness of social services.

What is the truth? The truth is that if we give the parents of young children, or the old-age pensioner, extra income we do so because we want them to consume more. We want to raise their standard of living. The extra goods and services which we want them to enjoy, the extra milk for children, the extra tobacco for old-age pensioners, must be produced and will use up productive resources which will then not be available for other goods. Moreover, once the extra milk has gone down the throats of children, or once the extra tobacco has literally "gone up in smoke" in the pipes of old-age pensioners, those extra goods are irrevocably gone and are not available for consumption by others as well. Thus, while it is perfectly true that the *money* given to those old-age pensioners simply represents a redistribution or "transfer," we ought to think of the extra *goods* transferred. The money transferred goes "round and round," and is spent back again by the recipients of social services into general circulation, or into the Exchequer. But the extra goods consumed by them will not go "round and round." Once given, they are gone. It is still true, of course, that the community *inclusive* of the recipients of social services is no worse off than before, but it is also clear that the community *exclusive* of the recipient must be worse off than it otherwise could be. While it is true that nothing is financially impossible which is physically possible, the reverse is also true. Nothing is financially possible which is physically impossible. It is physically impossible that the extra milk gone down the throats of children should be available as an extra bottle of whisky to the business man, and as it is physically impossible no financial manipulations can make it possible. No mental juggling with a transfer of incomes or the infinite circulation of money should obscure this basic fact. The question of priorities is a very definite and real one.

The idea that we can give extra goods and services to selected groups, such as young children or old people, without taking it away from anyone else, is based on the assumption of unemployment which has deeply affected our ways of thinking. It is perfectly true that, if unemployed resources are used, it is possible by financial manipulation to increase the consumption of some groups in such a way as to stimulate total demand and induce an increase in employment. In that case, the extra goods required can be supplied from the new flow of goods provided by the increased employment. In such a case it is possible to benefit some while not hurting others. In the topsy-turvy economics of unemployment, it becomes possible for a sensible group of people to pull themselves up by their own bootstraps. The fact that social services expenditure is a suitable method of increasing total demand and employment is always a potent argument in favour of the extension of such services in times of unemployment, or even in times of full employment if otherwise the maintenance of full employment might be rendered difficult. It must, however, be remembered that, when we assume an expansion of the post-war national income by some £1,500,000,000, this estimate has been arrived at by envisaging post-war unemployment to be much lower than the pre-war figure. If the fulfilment of this assumption is contingent upon the extension of social services, the case for them is very strong, and no real problem of priority is involved. But it would evidently be wrong for us—indeed, it would be a case of fraudulent double-counting—if we were first to assume that unemployment is being reduced and the national income expanded, and still tried to maintain that social services were costless and therefore

ought not to enter into the sorting out of priority claims. Either social services are costless because of unemployment —but in that case the resources available are correspondingly less—or else full employment has provided the resources, but in that case social services are not costless.

The table is now cleared for a discussion of the various priority claims on the post-war national income which are lined up at the present moment. Perhaps the best plan will be first to enumerate the extra claims on these resources, and then briefly discuss the general principles on which the allocation between them might be made.

First, there is defence. Many people believe that for some time to come this country must be prepared to maintain well-equipped armed services at a level greatly higher than pre-war. Conscription would mean the withdrawal of a large number of young men of certain age groups from production; the continued manufacture of military equipment would mean a diversion from useful production and exports.

The Importance of Foreign Investments

After defence, there is the claim of rebuilding the foreign investments which have been so badly depleted during the war, and of repaying some of the debts incurred since 1939. The expansion of exports which is required to compensate for the loss of foreign income must not be counted here, of course. We have already taken it into account in the previous article, when arriving at an assessment of probable post-war resources. But beyond the current expansion of exports to maintain the present position, it is likely that there will be advocates of a further expansion of exports to improve the post-war foreign situation. As long as there is the present unequal distribution of industry over the face of the world, there are some reasons why leading industrial countries ought to to be, on balance, lending countries and creditor countries. Now England, as we have seen, will find herself after the war in a position where she is shorn of most of her creditor claims. Thus, it is perfectly plausible to argue that, in the long run, England ought to try to get back to the pre-war volume of foreign investments.

This claim of foreign investments to a share in the extra resources will raise the issue of whether the pre-war foreign investments really did pay the country. Are foreign investments worthwhile? On that point it is easy to misinterpret the existing evidence as pointing to the conclusion that foreign investment is not a paying proposition. For have not foreign investments all gone down the drain? Have not many debtors defaulted on their commitments? Was there not constant friction over repayment? Did not the import surplus, representing the income from foreign investments, make the maintenance of full employment in this country so much more difficult? Did they not retard the mechanisation of home industries?

All this is undoubtedly true. Yet there is another side, equally impressive, to the balance sheet. Foreign investments kept going the pre-1914 system of free multilateral world trade which was of so much benefit to this country in developing her industry and obtaining cheap food and raw materials from abroad. It was foreign investments, not the gold standard, which kept things going. In the second place, foreign investments have proved a highly valuable war chest in two wars. After 1939, for instance they helped to bridge the gap until America was ready to substitute Lease-Lend for Cash-carry. They have helped to mobilise the latent and industrial resources of non-industrial countries overseas, raised standards of living abroad, and made them into powerful supports in times of war. They have enabled the country, through excess imports, to maintain a high standard of living, even during the economic blitz of 1930 to 1933. The claims of foreign investment to be rebuilt out of some share if the increased national income is one that is not easily dismissed.

The setting up of minimum wages for workers is another pressing claim that will have to be considered. An analysis of wage figures shows that heavy disparities in earnings have existed between industries. In some industries, wages have not been commensurate with the danger, risk and hard nature of the work involved; we might take coal mining as an example. In other low-paid occupations, the minimum earnings of the lower grades of labour were insufficient to maintain even a small family on an acceptable standard of living; cotton spinning is an example. In still other industries, the casual nature of the work had depressed earnings; dockers may serve as an example.

There will be a claim for raising the minimum level for wages either by the extension of the Trade Board system or else by the fixation of a national minimum wage. The unification of social services on the basis of a minimum level of subsistence in itself implies the idea of a national minimum wage. The trade unions have been greatly strengthened in membership and influence. Wage levels have been raised. Guaranteed minimum wages have been introduced for such occupations as dockers. Trade unions —and public opinion—will be strongly in favour of maintaining and extending these improvements. The establishment of a national guaranteed minimum wage for all may mean that wages are not to be less than, shall we say, £4 a week at 1938 prices (about £5 10s. or £6 0s. at probable post-war prices). This would in itself absorb an appreciable portion of the extra resources available. The worker—who is the main agent in producing the extra resources—evidently will have a claim to take out some benefit in the shape of higher wages, better standards of living and improved conditions of work. What place will be allocated to his claims in the scale of post-war priorities?

Family Allowances

The Government is already committed to a scheme of family allowances, which in cash and kind is reckoned to cost about £110,000,000. This in itself will absorb quite an appreciable fraction of the extra resources available. The necessity for lifting the standard of living of large families has become quite uncontroversial. It may even be expected that there will be pressure for the widening and extension of the family allowances scheme. Any such widening would raise new priority questions. How far the family allowances scheme in its entirety will represent a claim on the new resources available will depend on whether the payments made under this scheme to the parents of children will represent an addition to the total wages bill or a redistribution of it. The existence of the family allowance scheme will clearly make it possible, all things being equal, to reduce general wages somewhat. Let us note that the claims of large families under the family allowance scheme can clearly not be put forward

with the same conviction in wage negotiations. To an extent unknown at present, the scheme, therefore, will redistribute wages as between single workers or workers without children and workers with families. In so far as that goes it will clearly not represent any real claim on the extra resources. It is, however, likely that the claim will in fact result to a considerable extent in a net addition rather than a redistribution.

As to extra old-age pensions over and above the provision made before the war, the Government under the White Paper rates are now contemplating the extra allocation of £70,000,000 to old-age pensioners. A large proportion of the extra income given would absorb new resources. It is a well-known fact that any raising of the standard of living of old-age pensioners is a very consequential claim on the national income, because of the tendency of the numbers of old-age pensioners to rise steadily and rapidly. The extra resources required to pay the higher old-age pensions, therefore, will steadily grow in importance. The other social insurance concessions which the Government makes in the White Paper may be considered together. Higher rates for unemployment pay, better provision for ill persons and especially for their dependents, funeral grants, maternity benefits, and a general extension of the groups covered by the various social insurance provisions—under the White Paper plan, all these miscellaneous improvements are to distribute another £110,000,000 to their beneficiaries. Added to the family allowances and higher old-age pensions a total of £240,000,000 is set aside for cash improvements in social insurance provision.

All the priority claims which we have considered under the four previous headings came under the general class of improved consumption. Higher wages, in the form of all-round increments or of a lifting of the lowest standards, are meant to increase working-class standards of feeding, clothing, housing and comforts. Family allowances are meant to lift the large family to the same plane of comfort as the small one or the single earner. Old-age pensions are meant to raise the consumption of the ex-earner in retirement. The other miscellaneous improvements are meant to increase the consumption of those affected by the various economic hazards of life. In each case, it is *consumption* which is meant to be increased.

Adding to Social Capital

But what about the claims of capital accumulation? Within the national capital we can distinguish two separate types. First, there is the social or intangible capital of the country—the nation's health, skill, general education, housing comforts and general social environment. An addition to the social capital of this sort is closest to an increase in consumption in that it will involve direct benefits for the private individual. On the other hand, there is the productive capital of the country—its machinery, factories, transport system, and so on. From both these quarters there will be further pressing claims on the limited post-war resources.

Let us take the social capital first. The new Education Bill envisages ultimately an increase of the school leaving age to 16 and continued part-time education up to 18. This new programme will absorb teachers who will not be available for more direct production, it will require building resources for the provision of new schools, etc., it will keep juveniles from direct production either full-time or part-time. Whether we think of this problem in terms of manpower or finance, in either case the educational programme will be a weighty claimant in the post-war review. In addition to the direct absorption of manpower or finance it is also generally agreed that the salary—i.e. the standard of living—of present teachers must be improved, and improvements with a cost of the order of £60,000,000 are already as good as approved.

The case for giving educational expenditure very high priority is overwhelming. With the declining population we can no longer rely on sheer weight of numbers to obtain the required proportion of highly trained people and afford educational wastage. From now on it will be a question of making the very best out of each individual unit within the limited number available to us. Adaptability must be increased, both in connection with the full employment policy, and the greater importance of exports with the more ruthless competition attached to them. Adaptability, however, especially in an ageing population, requires that nimbleness of mind and willingness to change which can be expected and relied upon only in a highly educated and trained population. For an industrial nation with an uncertain future, investments in educating and training the population may be much less risky and much more remunerative than investment in direct tangible capital. The houses and factories which we build now may turn out to be the wrong sort of factories or to be situated in the wrong places. The extra education and technical knowledge which we impart now could still be put to any use which might be indicated at a later stage when the position has become clearer. Finally, a rise in the age of entry into industry will make vocational guidance more of a reality and less of a farce. As long as people enter industry at the age of 14 they have not the minimum of geographical mobility that is required if they are to move to those jobs for which they are best fitted. At some future date after the age of entry has been raised, let us suppose, to 18 we may look forward to a state of affairs where we can really put people into those occupations where they want to be and where they are likely to make good. Finally, with improving wealth people will increasingly want to partake of the extra income, not in terms of more goods, but in terms of more leisure. It will become essential, therefore, to provide people with the means of enjoying their leisure without using up an excessive amount of economic resources in the process. The motor cars required simply to help an uneducated population to kill its leisure time by dashing about the country are not a real addition to our standards of living. An educated population which will take its leisure enjoyment in walking and reading may be happier and more prosperous in every respect. Summing up, the the case of extra educational expenditure is one that looks exceptionally strong.

After education, there is health. The country is already as good as committed to an expenditure on health services very much above pre-war levels. The National Health Service explained in the Government White Paper is reckoned to cost £170,000,000 and even that is generally believed to be an under-estimate. Again, health expenditure may be partly productive, making a repayment in

more output and higher efficiency, but this would probably be considered a long-term speculation rather than an immediate repayment. It may be best to envisage the extra health expenditure as expenditure designed to raise popular welfare and standards of living.

Town and Country Planning will be another potent source of expenditure on social capital. All we have in this field is the Uthwatt Report, a White Paper on the use of land, and a bill which deals with a strictly limited part of the whole field, namely, the blitzed and blighted areas. So we are still largely in the dark about what is going to happen. Will it be central development requiring a clearing up of the centres of our towns, or will it be the building of new satellite towns; will it be suburban development or will it be a revival of rural industries? We do not know yet. All we know for certain is that a great amount of communal activity will be directed to the proper lay-out of towns with their houses, transport and communications. These activities will cost a great deal financially. No doubt a good deal of the expenditure will be recovered by betterment and the projected tax on increased site values. Even so, if we think of it in terms of the manpower budget, there is no doubt that the Town Planning movement will lead to a volume of activity in pulling up old things and developing new ones which will appreciably add to the drain on post-war resources. The new neighbourhood units will require new communal buildings and community centres. The creation of "green belts," the re-shuffling of transport facilities, all these will absorb manpower.

Far and away the greatest strain on social capital will come from the housing end. A good deal had been done in the 1930's. Before this war the percentage of over-crowding had been appreciably reduced and the state had been reached where England, as the first of all countries, could think of making over-crowding a statutory offence. The slum-clearance programmes had made great inroads into that disgraceful heritage of industrial civilisation, but the war has put us back rather below where we started from in this great drive. The time when the over-crowding provisions of the 1936 Housing Act can be put into operation again looks farther off now than ever. The Government itself has envisaged a building industry extended for an appreciable period to employ $1\frac{1}{4}$ million men—and that was before the flying bomb. Add to this the extra labour required to provide the extra fittings, furniture, etc. The normal building industry will have to be supplemented in the first years after the war by unorthodox methods: pre-fabricated houses, steel units, etc. On psychological grounds housing is bound to occupy something like A.1. priority, and there may be popular pressure to cut down everything that would possibly interfere with housing. At the same time there is no other field where thought before action is so important. Houses themselves are meant to last for 50 years or so. Moreover once an area has been developed for housing purposes it cannot be re-converted to other uses, except at great loss. Therefore it is absolutely essential to erect the new houses in the right places. Thus housing must be closely co-ordinated with the location of industry if we want to avoid post-war troubles.

The housing problem is further complicated by the fact that building costs have soared during the war, and it is far from certain that they will come back to their previous level. Here of course is a link between the provision of the social capital of housing and the equipment and organisation of the building industry. The claims of housing alone will be fully sufficient to absorb for any foreseeable length of time the £1,500,000,000 of extra resources that may materialise (more than that cannot be expected to become available after the war on any responsible reckoning at the present time). From the financial angle, the solution of the problem seems to require large subsidies towards the building of these houses, but the form and size of these subsidies are completely in the air at the present time.

Increasing Production Capacity

Last but not least there is the ordinary productive capital of the country's industry. Recent investigations and comparisons with other countries (especially America) have shown that this country has lagged greatly behind in capital equipment. The amount of capital equipment for work measured in horse-power per head is in the United States about 2 to 3 times what it is in this country. Nor is this surprising if we remember that England over more than a century has invested her savings in investments abroad rather than adding to the capital equipment of her own industries. If we try to calculate in terms of money the resources that will be required to double industrial equipment within the next 15 years and thus bring the English figure up to the American level it turns out to be an astronomical proposition. Expenditure on this item will have to be scaled down to fit in with other claimants, but even so it will be a very pressing and hustling claimant. The need for increased exports, and the manpower shortage which will go with full employment and the declining population, will constantly add to this pressure and to the pressure for increased mechanisation. There will also be the need to make good damage to machinery which has been largely worn out or else re-converted to war use during the war. Nor is it simply a question of increasing the equipment of the existing industries. Technical progress has been accelerated by the war. If this country is to take its place among the leading industrial nations, new industries will have to be built up, such as plastics, oil refining, etc. It is characteristic of all these new industries that they require the expenditure of vast amounts of initial capital.

It is impossible at the present time to place any actual money figure against the total or annual outlay on new capital equipment. It is safe to say that, if additions to the productive capital of the country could be planned as an A.1. priority to the sole exclusion of everything else, that item (just like housing) would be sufficient to absorb a full £1,000,000,000 worth of resources for generations to come. As a reasonable demand it has been advocated that the proportion of the national income—about 5%—which used to go towards adding to the national capital should be at least doubled after the War. If this demand is applied to a post-war national income of some £8,000,000,000 it would require an extra £400,000,000, which is a very big chunk out of any extra resources likely to be available.

We are now at the end of our list. It is like a nightmare dream, with claimants pressing on all sides, each of them

with a sound priority argument to his support. And yet the overall means available to satisfy their claims are insufficient to do all these things in full measure at the same time.

What then shall be done? Shall we try to do a bit of everything or shall we pick out a few items and give them an A.1. priority? From a purely economic point of view clearly the first course is indicated. Peace-time conditions are different from war. In war, war production receives an A.1. priority for success in war is an absolute condition of survival itself. But peace-time economics are not just a matter of survival itself, but poses the question—In what direction shall our standard of living be added to? Just as a private individual does not spend his money on clothing, shall we say, to the exclusion of everything else but spreads it in various directions to obtain maximum satisfaction, so the community ought to behave. The building of new schools of certain types and in certain places should get priority over the building of houses, but the building of houses of certain types and in certain places also ought to get priority over the building of schools in general, and so on. A limited advance in all directions is preferable to a rapid but lop-sided advance.

There are, however, arguments on the other side. Sir William Beveridge, especially in his new book, *Full Employment in a Free Society*, has advocated the "over-riding social purpose", comparable to the part which war production plays in times of war. There may be great advantages in that course. Psychologically it will be easier to harness the enthusiasm and co-operation of the general population that is so essential in a vital democracy to a limited project capable of fulfilment in a definite time than to a scattered advance. It is also possible that the fixing of the A.1. priority may make it easier to maintain full employment, insofar that the attempt to fulfil any single A.1. priority represents something like a bottomless pit which swallows up manpower without fear of exhaustion. Whether these arguments are sufficient to establish a case for an A.1. priority for any of the things is not for an economist to say. The full employment argument is perhaps not quite so important as it may appear at first sight. This article has shown that there are so many claimants on all sides that even a limited advance in all directions at the same time will be perfectly capable of draining the available resources to the utmost without fear of unemployment.

The Man who Discovered X-Rays

A CURIOUS point in books on X-rays and in accounts of the phenomena accompanying the high-tension discharge through gases is the lack of attention given to Röntgen, the centenary of whose birth falls on March 27, and his work on X-rays before he announced his discovery to the world of science. There has been a tendency to regard his discovery (made in 1895) as a "lucky" one, because he happened to screen his discharge tube with black paper and, holding it near a card covered with barium platinocyanide, noticed the fluorescent effect which other workers had also seen. Yet the history of science is full of such chance observations, of such elements of luck causing experimenters to arrange certain apparatus in certain ways and leading to important discoveries in the hands of trained observers able to interpret the results which followed. Sir Herbert Jackson certainly came near to "discovering" X-rays when he observed the fluorescent effect of rays which had been led out of the discharge tube through a thin metal window—an idea due to Lenard, pupil of Hertz, who had also noticed that the rays could pass through his hand. But, as Jackson remarked, "just as I was puzzling over this, Röntgen's discovery was published and I saw the explanation of my own results". That is why Röntgen must be given credit for playing the master card after others like Faraday, Crookes, Plucker, Hittorf and Lenard had had their say on the effects seen in discharge tubes. But the incident contains no such luck as that which attaches to one tale of Röntgen that is now known to be a legend, viz. the account of him laying a discharge tube on a book luckily containing a flat key and luckily having a loaded photographic plate holder underneath—experimenters in science do not lay electrical apparatus connected to a high-tension supply on any odd book!

What sort of a man was Röntgen is an obvious question on the occasion of his centenary. It is a question often asked since histories of science are content but to mention his name. Röntgen was the son of a cloth merchant, his mother came from a Dutch family, and he himself was born at Lennep on the Lower Rhine. He spent his boyhood in Holland, was expelled from school because of some prank, and so found his way to Zurich Polytechnic. There he came under the influence of those two physicists, Clausius and Kundt, the latter in particular attracting the youth, for when Röntgen went later to Strasbourg it was because Kundt had gone there. Rising by the usual academic steps to a professorship at Giessen, Röntgen finally arrived at Wurzburg in 1888 to succeed the eminent Kohlrausch as Professor of Physics and Director of the Institute.

One need not record in full that great chapter concerning the discharge tube, for it is one of the high lights in the history of physics. Hawksbee began it as early as 1705 with his mercury flashing in an evacuated vessel because of the electrostatic charges and the mercury vapour present. Next the Abbe Nollet and his egg-shaped bulbs and vacuum pump and electrical machine conjured forth by that great showman among philosophers, Otto von Guericke, mayor of Magdeburg. Later the scene shifted to England with William Morgan and Davy, with Faraday and his "dark space" which Crookes found to be advanced up the tube when the pressures became lower still. But it was Röntgen, an almost unknown scientist of sleepy Wurzburg, who roused the attention of Europe and America when, after six weeks intensive study in his laboratory, he announced his X-rays—"X for the sake of brevity"—at the December meeting of the Wurzburg Physico-Medical Society. The world's press trumpeted the news with a flourish: "The noise of war's alarm should not distract attention from the marvellous triumph of science which is reported from Vienna. It is announced that Professor Röntgen of the Wurzburg University has discovered a light which for the purposes of photography will penetrate wood, cloth and most other organic substances". Röntgen shared with Lenard the Rumford medal of the Royal Society and later was awarded the Nobel Prize, particularly since he contributed to other branches of physics. But his "X-rays" remained thus and never became "Röntgen rays" to perpetuate this quiet, unassuming bearded philosopher, who sought no gain from his discovery which has become a master key in science and industry apart from its humane uses in hospitals.

M. SCHOFIELD.

Fighting the Malaria Germ

SYNTHETIC DRUGS REPLACE QUININE

SINCE earliest times malaria has caused more death and suffering than any other single disease. It is estimated that 3,000,000 people die each year from its effects; in India alone there are about 1,400,000 deaths from malaria. Wherever it is endemic it lowers the vitality of the whole population; the victims do not die quickly upon contracting the disease, but with their deterioration slowly seeps away the strength of the civilisation to which they belong. The Roman Empire was pillaged by barbarians, but it has been said that malaria and plague did as much to conquer the Romans as did the Goths and Vandals.

In every military campaign fought in tropical and sub-tropical zones adequate control of malaria is of the utmost importance. Its incidence has often meant the difference between victory and defeat. Italy and Sicily are malarious as well as North Africa, the Balkans, Syria, Persia, India and Burma and the South-West Pacific theatre of war. It is not uncommon to find that in many of these regions casualties due to malaria exceed in number those due to wounds. For instance, in the last war there were nearly 60,000 cases of malaria on the Balkan front in the period March-September 1918. It has been stated in this war that 80% of the Australian troops who landed in New Guinea went down with malaria in the first few weeks. General Montgomery has stated that malaria was responsible for more casualties in the Sicilian campaign than all other causes put together.

The term "malaria" is applied to certain fevers which are the outcome of infection by protozoan parasites belonging to the genus *Plasmodium*. For centuries it was connected in people's minds with marshes. The part that the mosquitoes which breed there play in carrying the disease was not recognised, and the transmission was wrongly attributed to the evil smells instead of to the insects; hence it gained the name *mal aria*—Italian for bad air. The parasite as first identified by Laveran on November 6, 1880, in Constantine, Algeria. It was not until 15 years later that Sir Ronald Ross of the Indian Medical Service showed the inter-relationship of man and mosquito. Conjecturing that some species of mosquito removed the malarial parasite from the blood of one man and returned it to the blood of the next victim, Ross worked on the problem from 1895 to 1898 when he was able to demonstrate conclusively the complete life cycle of an allied species of malarial parasite which has birds and mosquitoes as its alternate hosts. The transmission of human malaria was subsequently worked out by English and Italian workers. These discoveries were epoch-making for they opened up new possibilities in the field of malarial control.

It was clear that if infected mosquitoes could be kept at a distance or better still were killed or prevented from breeding then human beings could not contract malaria. Fracturing the life cycle of the malarial parasite by controlling the mosquito is now practised on a large scale, and has had great success in certain localities. Modern and potent insecticides such as D.D.T. may well increase the efficiency with which mosquito control can be carried out.

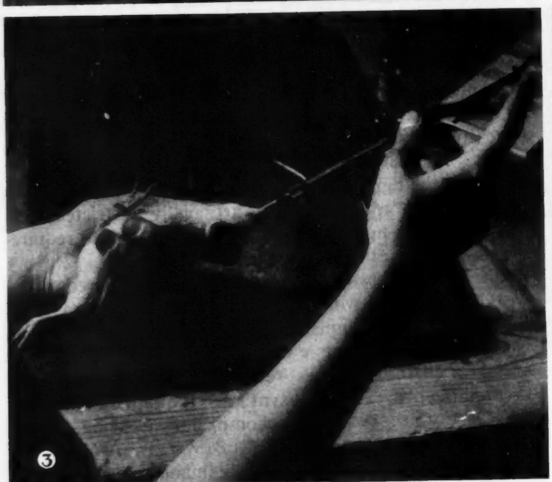
In many places adequate control of mosquitoes is difficult and recourse has to be made to prophylactic and curative treatment of the human patients. The latter approach is the one on which reliance has to be placed at present when dealing with the malarial problem of armies engaged in warfare with rapidly moving fronts.

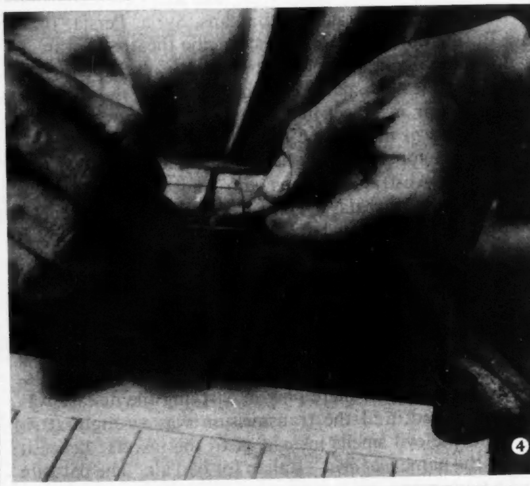
For a long time quinine was the only drug available for treating the disease, but its production has never been able to keep pace with the demand. Comparatively recent research, notably that carried out by the late Professor Warrington Yorke at Liverpool, established the fact that quinine cannot absolutely prevent the development of malaria in a person bitten by an infected mosquito even though it is administered in massive doses; nor can quinine "abort" infection in the very early stage when the parasites in the blood are relatively few, nor can it prevent relapses. It can however exert a high clinically curative effect on malaria patients. Quinine is thus a valuable remedy. The demands for it are colossal. It has been calculated that 60,000 tons of quinine would be required each year if it were to be made available to all who live in malarious places. In 1939 world production of quinine was only 600 tons (the figure is less than the capacity of the plantations, output of which was artificially restricted)—no more than one-hundredth of the estimated world requirements.

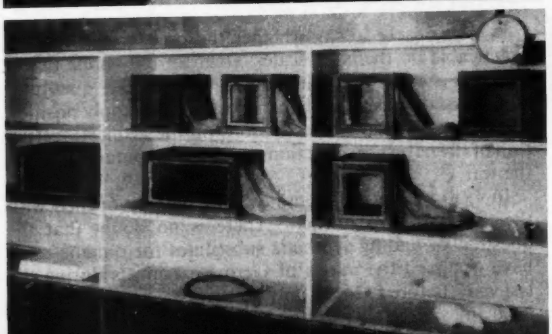
The hope of synthesising quinine has inspired many workers. Readers will remember that as long ago as 1856 Sir William Perkin aimed at this synthesis; his experiments were a complete failure, a failure which is immortal in the annals of chemistry since it resulted in the discovery of the first aniline dye. The total synthesis of quinine eventuated only last year—1944—its accomplishment being due to two young American chemists, R. B. Woodward and W. E. Doering, whose investigations were financed by a company requiring quinine for non-medicinal purposes.

It is too early to say whether the process will become practicable on the large scale. One can only hope that it will, for synthetic production in commercial quantities would not only be directly beneficial to the supply position but would also have repercussions on the artificial restriction of the natural production which was maintained before the war.

In 1910 the era of scientific chemotherapy opened with the discoveries of Ehrlich. There is no doubt that the question of finding synthetic substitutes for quinine must have occupied the minds of German chemists during the last war. Before 1924 the only synthetic materials known to have any appreciable anti-malarial action were some of the arsenicals and the antiseptic dyestuff called methylene blue. The first real advance towards a synthetic substitute for quinine was made by Schuleman in collaboration with Roehl who developed a technique for testing anti-malarial activity using a form of malaria occurring in birds. The result of these pioneer researches was the introduction (1924) into malaria chemotherapy of ***Plasmoquine*** (the Americans follow German usage in their nomenclature,







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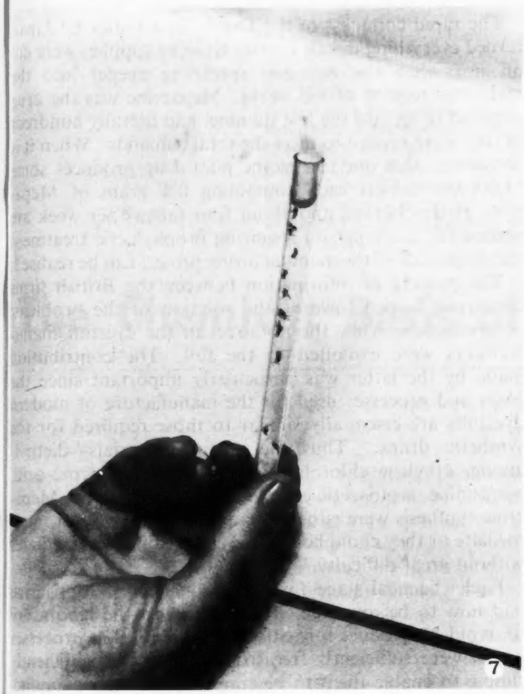

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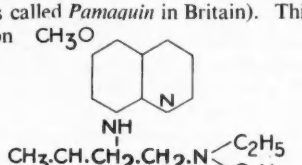
though the drug is called *Pamaquin* in Britain). This drug has the constitution



and the chemical name of 8-(8-diethylamino-α-methylbutylamino)-6-methoxyquinol.

Although active against certain forms of malaria Pamaquin has little effect on the asexual cycle of the parasite in the human being. (It is the completion of each asexual cycle—or schizogony—that leads to the onset of fever in the patient. The periodic crises are brought about by the toxins which are realeased when the blood corpuscles rupture and set free the new-born schizozoites—*see* Fig. 9). However Pamaquin is still widely used for certain purposes in combating malaria. Its discovery opened up a new field of research, and eventually the German firm of Bayer perfected *Atebrin*, a drug which to-day suffers from a surfeit of synonyms, being otherwise known as *Atabrine* (United States), *Mepacrine* (Britain), and *Quinacrine* (France). The constitution of Mepacrine is similar to that of Pamaquin except that the basic aliphatic side chain is attached to an acridine nucleus instead of to a quinoline nucleus.

Mepacrine is less toxic than Pamaquin, and some five times as active as quinine in destroying the malarial parasite in its asexual stage. It is thus a most effective substitute for quinine, although like the natural drug it has no action of the sexual cells or gametocytes of malignant tertian malaria. It is also extremely bitter to taste, and has some tendency to cause nausea, while its intense yellow colour causes some pigmentation of the skin which sometimes leads to the misguided allegation that it causes liver disorder.

Prior to the war Germany had a virtual world monopoly over the production of both Plasmoquine and Atebrin. This was due partly to the fact that other countries were content to rely upon quinine and world interest in the synthetic anti-malarials was at best lukewarm. Germany's intensive effort to free herself from dependence upon natural quinine

E potency of anti-malarial drugs is tested against a form of malaria germ that infects birds. **1.**—As the parasite is ntained within the red blood corpuscles it can be transmitted from bird to bird by simply inoculating one bird with od from an infected bird. If a large number of birds are to be infected, blood is taken from the heart of a freshly led bird carrying the malarial germ. **2.**—The infected blood is then injected into the jugular vein of the experimental ick. **3.**—Infected chicks are then given the drugs under test by means of a catheter tuber which is put down their roat so that the end of it reaches the stomach. **4.**—At the end of the experiment the success or otherwise of the drugs estimated by examining under a microscope stained smears of the blood of the chicks for parasites. **5.**—In nature alaria is transmitted by mosquitoes and for some experiments in the laboratory it is necessary to duplicate natural nditions as closely as possible, and consequently the malaria of chicks must then be transferred by means of mositoes. For this purpose the insects are bred in a specially built room, the temperature and humidity of which are th controlled. **6 & 7.**—The insects are sucked into a glass tube. **8.**—Each mosquito is dissected under a dissecting croscope; cysts on the walls of the insect's alimentary canal indicate the presence of the malaria germ. (*Photographs courtesy of I.C.I., Ltd.*).

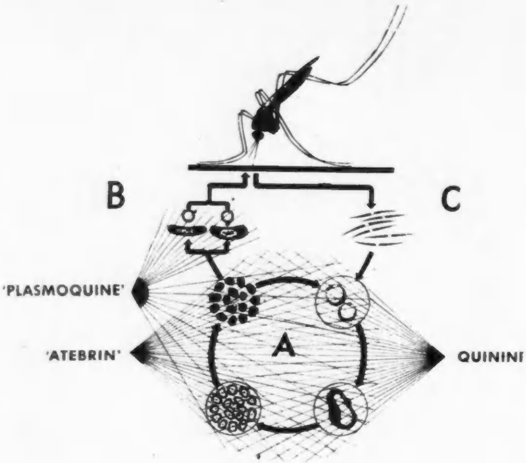


FIG. 9.—Indicating the susceptibility to drugs of the malaria germ at the various stages in its life history. A, the phase called schizogony, in which the parasite undergoes asexual reproduction within the containing red blood corpuscle to yield schizozoites which are released by the break-down of the corpuscle and proceed to infect new blood cells. B, the sex mother cells (gamonts) which only develop after transfer to the mosquito, giving rise to gametes; the union of the gametes to form a zygote is followed by profuse asexual reproduction leading to the production of large numbers of needle-shaped sporozoites (C) which are injected back into man by the mosquito. Mepacrine and quinine destroy the asexual stages; plasmoquine is relatively ineffective. The gamonts of all species of malaria are killed by plasmoquine; the gamonts of the species *Plasmodium vivax* and *P. malariae* are attacked also by mepacrine and quinine, but these drugs fail to destroy gamonts of *P. falciparum*.

was only in line with her determination to secure her own supplies of fats, petrol and of rubber, also by synthesis; it was part of a policy of self-sufficiency which was necessary once Germany was committed to a policy of expansion by conquest.

The possibility of war with Germany led to British plans for the preparation of Mepacrine and Pamaquin here should the need arise. The chemical constitution and method of manufacture of these two drugs had been published in patent specifications. These recipes had to be carefully confirmed by synthesising the substances in British laboratories and proving beyond all doubt that they were identical chemically and in therapeutic effect with the active constituents of the German tablets. The Germans had protected their discoveries to the extent of patenting all conceivable ways of making the drugs without giving any definite clue as to which were the most efficient methods of manufacture. A big research effort was therefore necessary before it could be discovered which were the most practicable processes, from which the most economical could then be selected by further experiment. By 1939 the initial difficulties had been largely overcome and small amounts of both drugs were being produced here. Quinine was then in good supply and the small demand for the synthetics was met without much difficulty.

The rapid conquest of the Dutch East Indies by Japan turned everything upside-down. Quinine supplies were cut off just when the war was spreading deeper into the malarious regions of the world. Mepacrine was the drug required to replace the lost quinine, and literally hundreds of tons were needed to meet the total demands. When it is considered that one ton of the pure drug produces some 11,000,000 tablets each containing 0·1 gram of Mepacrine Hydrochloride and about four tablets per week are needed for every person requiring prophylactic treatment the magnitude of the manufacturing project can be realised.

The pooling of information between the British firms concerned helped towards the solution of the problems of production, while the resources of the dyestuff manufacturers were exploited to the full. The contribution made by the latter was particularly important since the plant and processes used for the manufacture of modern dyestuffs are essentially similar to those required for the synthetic drugs. Thus the starting materials—diethylamine, ethylene chlorohydrin, 2:4-dichlorobenzoic acid, *p*-anisidine, acetoacetic ester, etc.—required for the Mepacrine synthesis were either already in use as dyestuff intermediate or they could be made from existing intermediates without great difficulty.

Each chemical stage for the production of Mepacrine had now to be investigated thoroughly in the laboratory to avoid by-product formation, and to develop processes which were sufficiently free from hazard and sufficiently simple to enable them to be transferred to the manufacturing scale with certainty of success. Only the industrial organic chemist knows the difficulties involved in this work and the high degree of control essential to obtain consistently high yields of perfectly pure product. However, difficulties were overcome in record time and the research chemist, ably supported by works' chemists, engineers, chemical engineers, chemical process workers, and other technicians associated with the British dyestuffs and pharmaceutical industries, produced manufacturing processes which were at least the equal of, and probably superior in many respects to the original German processes. The laboratory achievements were rapidly followed up, and plants previously used for the manufacture of less essential products, medicinals and in particular dyestuffs, were modified to accommodate the new processes. Results were so successful that, over a period of only two years, the British production of mepacrine rose steadily from a mere trickle to many hundreds of pounds per day; one firm last year, for example, announced its intention of producing sufficient for 1000 million tablets annually.

Mepacrine production has similarly been developed, although more recently in the United States (*see* DISCOVERY October 1943, p. 322), and, with new plants rapidly coming into full production in America and Britain, ample supplies of mepacrine for the armed forces of the United Nations and for war-time and peace-time civilian needs are assured. With process improvements and an ever-increasing scale of production, the manufacturing cost of mepacrine has been progressively reduced and its present-day cost of production is very much less than the pre-war selling price of the German drug.

The above account concerns the purely chemical aspect of mepacrine production, but there have also been big advances in this country in chemotherapeutic research.

[*Concluded on page* 86

"THE Unity and Power of Biology" was the title of Dr. Darlington's lecture to the January conference of the British Association. That unity derives from a new synthesis in which chemistry and physics are linked with biology. Behind the synthesis, which is described in more detail in this article, lie three fundamental discoveries—Mendel's findings of 1866 that heredity depended upon particles that do not mix or blend, Hertwig's discovery in 1875 that it was the nuclei of the germ cells that had to fuse if fertilisation was to occur and the discovery of Miescher in 1871 of what are called the nucleoproteins, the proteins he found in the nuclei of animal cells. "We can now tell," Dr. Darlington told the British Association, "that the particles which Mendel inferred lie inside the cell nucleus whose movements Hertwig followed. And we can show they consist of the nucleoproteins that Miescher isolated." Chromosomes, because of their nucleoprotein content, can be subjected to all the tricks of chemical and physical analysis, and as strings of genes they can be changed or recombined in breeding experiments. Never before have three such entirely different methods of attack been brought to bear on one kind of biological structure. Because of the importance of Dr. Darlington's article, which we feel will interest many non-biologists, DISCOVERY has departed from its usual practice and publishes at the end of this article a detailed set of references for those who wish to pursue this provocative line of speculation.

The Chemical Basis of Heredity & Development

C. D. DARLINGTON, F.R.S.

PLANTS and animals are in general, made up of cells each of which is the sphere of action of a small body within it, the nucleus. This sphere of action is limited by the limitations of diffusion. Growth therefore requires division of the cell which in turn requires division of the nucleus. The nucleus lies either centrally or in the part of the cell where its greatest activity is going on.

How do we know that the cell is the sphere of action of a nucleus? If a fertilised egg loses a part of its cytoplasm, that is the substance outside the nucleus, it is just so much smaller; if it loses a part of its nucleus—even the smallest part—it dies. Thus the nucleus seems to control the activity of the cell in development. It is the cell's only specific and indispensable organ. And since development is the expression of heredity, it should be of equal importance in heredity. This in turn is clear from the contributions to heredity of egg and sperm, which are almost equal although their contents apart from the nucleus are so vastly different.

Now control may mean many things. Let us first see how the nucleus exercises its control. Its life cycle tells us something. Its division (or, if you like, multiplication) usually takes place in step with that of the cell. The nucleus resolves itself into visibly separate bodies, the chromosomes. The foundation of each of these is a protein fibre (chromonema) which is coiled and charged with a substance called *desoxyribose nucleic acid*. This acid absorbs basic dyes and so gives the chromosome its capacity for staining and hence its name of "colour-body". The fibre is coiled throughout its length except at one point, the *centromere*, which therefore appears as a constriction (Figs. 1A, 5). Already when the chromosomes become visible the fibre can be seen to be double. It has divided, or rather reproduced, inside the nucleus at about the time (as X-ray effects show) when the nucleic acid begins to be attached to it. When its coiling is complete, the two halves of each chromosome are pulled by the halves of its divided centromere to opposite daughter cells and the two chromosome groups form opposite daughter nuclei (Fig. 1B). The whole action is called mitosis.

Inside the daughter nuclei the active groups or genes resume their work. They sweat off their nucleic acid together with the products of their own activity, and the chromosome fibres uncoil. If the cell is engaged in protein formation (as shown by growth or secretion) the nucleus swells and rapidly secretes within itself a structureless body, the nucleolus, containing proteins and *ribose nucleic acid*. In young growing eggs these two products of nuclear activity can also be seen accumulating in the cytoplasm next to the surface of the nucleus. Ribose nucleic acid is present in the cytoplasm in quantities proportionate to the rate of protein production, that is of growth or secretion. And within the nucleus the size of the nucleolus is also proportionate.

Thus the two nucleic acids seem to be responsible for two contrasted activities: the desoxyribose for the reproduction of chromosomes and especially of their active groups which we call genes; the ribose for the production or reproduction of other proteins. Amongst viruses, the smaller and simpler work with ribose nucleic acid, the larger and more complex with desoxyribose. Between them these two types of molecule are the agents of heredity, development and infection.

Formerly the two nucleic acids were attached by name, not to the nucleus and the cytoplasm, but to the thymus gland and to yeast, or by an erroneous contrast, to animals and to plants. This was, as we now see, quite the wrong trail to follow, for it is precisely in the nucleic acids that we find the common chemical denominator of plants and animals, just as in the chromosomes we find their common mechanical and physiological denominator. At this level botany and zoology speak, or at least should speak, the same language.

How do we recognise the two nucleic acids? In general structure they are similar. They are made up in series of plates, separately called *nucleotides*, all of which are composed of the same three types of unit, base—sugar—phosphoric acid, which can be separately identified in different ways (*see* p. 82). The bases, which are believed to be alternately purines and pyrimidines in successive nucleotides, can be recognised by their special properties of ultra-violet absorption with a maximum at 2600 A°. The phosphoric acid can be determined by a combined chemical and spectroscopic test. The sugar can be recognised

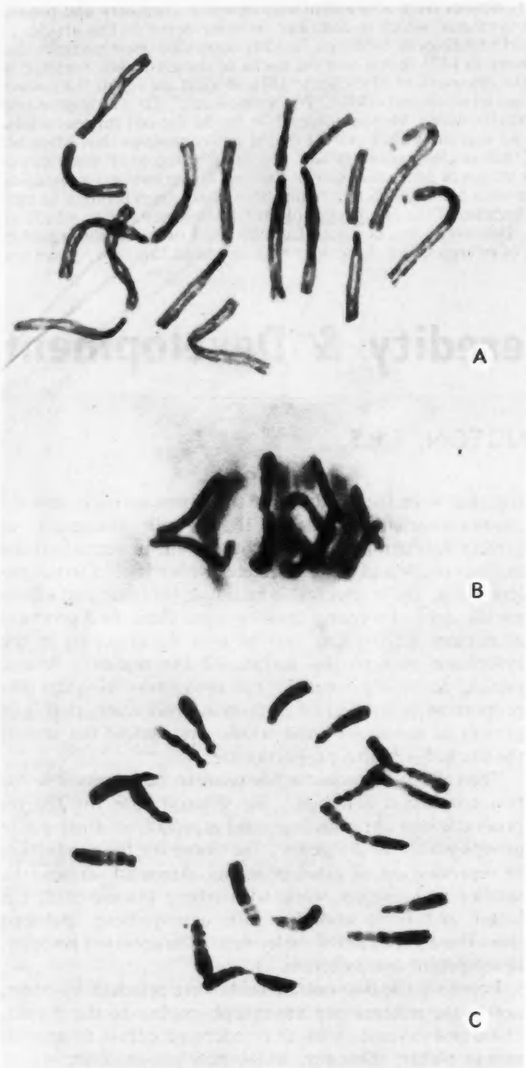


FIG. 1. (A)—The ten chromosomes of a lily, *Trillium stylosum*, at mitosis in a root, divided and ready to separate to daughter cells. Note the centromere constriction of each and the similar shapes of pairs. × 750.

(B)—The daughter chromosomes of a garden tulip separating in an embryo-sac mitosis; seen from the side. × 1250.

(C)—Seventeen chromosomes in the pollen grain of a lily, *Fritillaria pudica*, showing nucleic acid starvation of the heterochromatin segments lying near the centromere in most chromosomes. Stained with Feulgen's reagent. × 750. (*Photographs by L. F. La Cour*).

readily in the desoxyribose form, for this gives Schiff's aldehyde reaction which is the basis of Feulgen's method of staining chromosomes.[1] The alternative ribose group can be recognised, with suitable precautions, by staining with pyronin in Pappenheim's methyl-green-pyronin method.

Chemically the important distinction between the two nucleic acids consists in the sugar group of each nucleotide and a pyrimidine of one of them. Mechanically the important distinction consists in the capacity of the chromosome nucleotides to undergo seemingly endless repetition. By this polymerisation they make a column, like pennies, as Astbury puts it, or perhaps even more like a spiral staircase or the ribs of a collapsible fan. This column attached to the chromosome is, as we shall see, much stronger than the polypeptide chains of the chromosome fibre itself. The polymerisation of the ribose nucleotides on the other hand seems to be limited to some 60 nucleotides. Last of all there is a physiological distinction. Enzymatically the chromosome nucleic acid is inactive, the cytoplasmic one is active.

Between the two contrasted molecular agents and the two contrasted phases of chromosome life there is a strict correspondence. On the one hand we see the chromosomes changing from their chemically-active dispersed condition inside the nucleus to their mechanically-active compact condition during mitosis. On the other hand we see the nucleolus dissolving and its chemically-active ribose nucleic acid being reconstituted in the mechanically-active desoxyribose form which we find attached to the chromosomes. And when its attachment is complete the chromosome fibres are spiralised and the genes on these fibres are safely locked up. Thus in the mitotic cycle there follow one another, with a regulated frequency, phases of nucleic acid attachment and detachment to and from the genes, whose activity is thus switched from reproducing themselves to producing cell materials, and back again.

All cells with a differentiating future in front of them pass through cycles of mitosis. In specialised tissues, however, where differentiation is fixed and development limited, the cyclical alternation is not indispensable. In flies, many tissues—such as the salivary glands—have adopted a direct system of development. Production and reproduction go on side by side without any kind of intervening mitosis. In consequence the number of chromosomes or gene strings in the nucleus doubles and redoubles until 64, 128, 256 or even 512 are reached. The ordinary double or diploid nucleus thus becomes surreptitiously polyploid. Unlimited reproduction is combined with unlimited attraction and homologous pairs of compound chromosomes lie side by side, gene by gene. The secretory activity of the cell and its control by the giant nucleus continues without interruption. In these circumstances the nucleic acid remains attached to the genes which, being separated (as Caspersson has shown) by the protein products of their own activity, become visible as separate, deeply staining, bodies, the chromomeres. The chromosomes thus appear as banded ribbons, each made up of 256 threads or more and each stretched to about a quarter of a millimeter, ten or twenty times their proper resting stage length (Fig. 3).

[1] Hydrolysis in normal hydrochloric acid at 60° C. for 6 minutes followed by staining in leuco-basic fuchsin for 2 hours.

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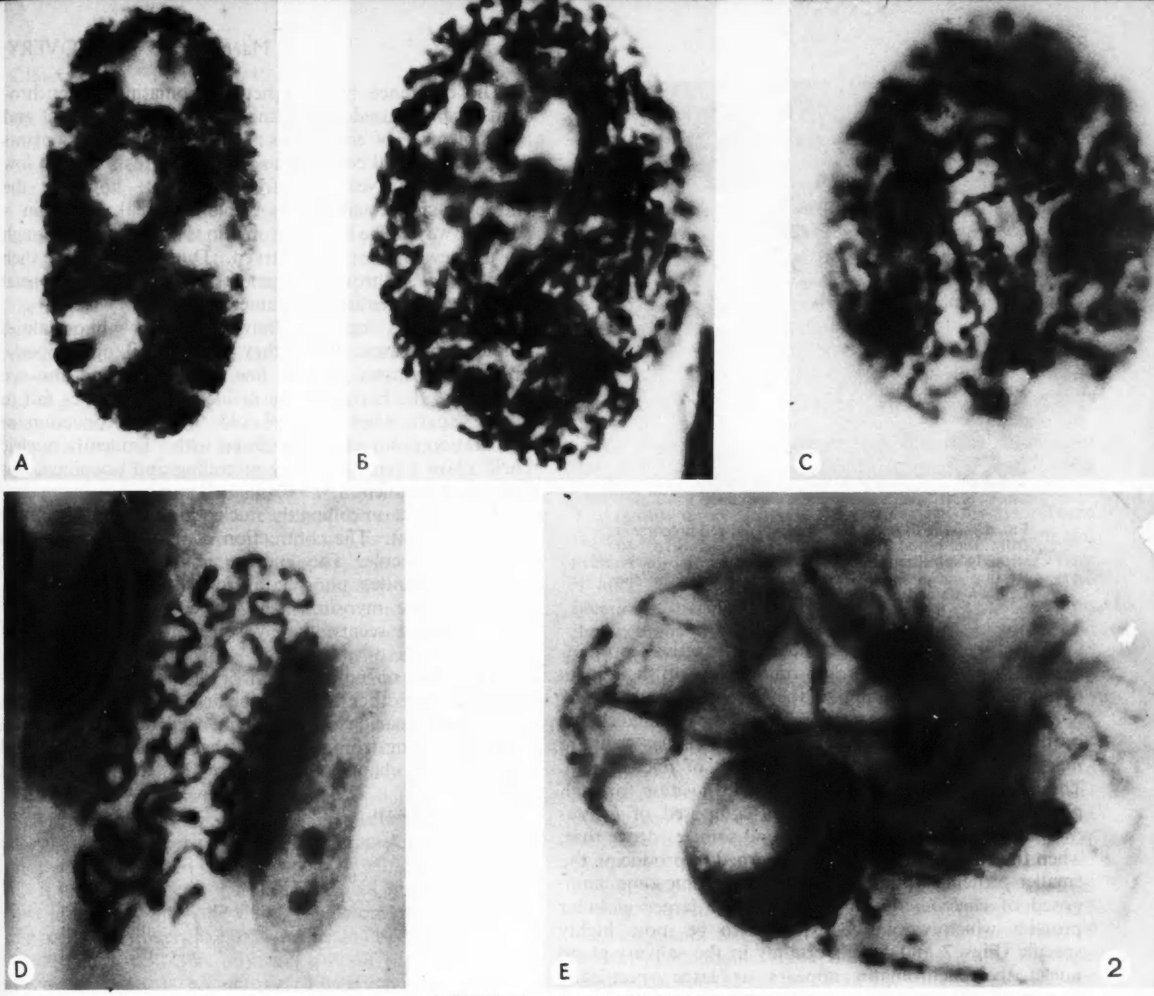


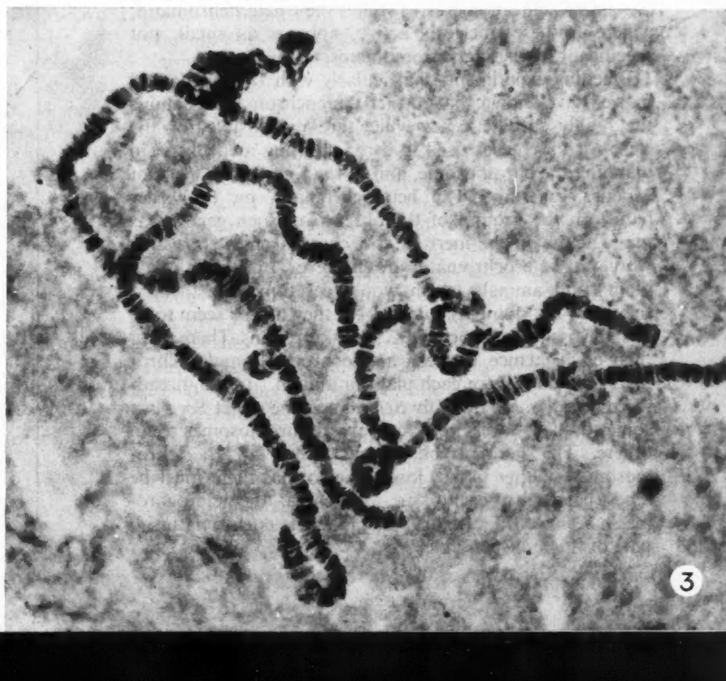


FIG. 2. (A to C)—*Fritillaria pudica* root tip nuclei in stages entering mitosis (resting stage to prophase) with nucleic acid increasing on the chromosomes. Black are the deeply charged heterochromatin segments while the transparent spaces are the nucleoli unstained with Feulgen. × 3000.
(D)—Fibroblasts in a rabbit tissue with resting and prophase nuclei. Heterochromatin deeply stained with Feulgen, no nucleoli. × 3500. (*Photograph by Dr. C. Robinow of the Strangeways Laboratory*).
(E)—Nucleus in an embryo-sac mother cell of *Fritillaria pudica* (prophase of meiosis) showing nucleolus lightly stained with osmic acid, heterochromatin as lumps deeply stained, euchromatin appearing as threads beaded with genes. × 2000.

FIG. 3.—Flattened salivary gland nucleus of *Drosophila melanogaster* showing the chromosomes in three pairs, each pair making a ribbon banded with genes separated by bands of unstained protein. Loops indicate inequality, i.e. hybridity, of the paired chromosomes. Stained with aceto-carmine. 4mm. objective. × 650. (*Photograph by Dr. P. C. Koller of the Royal Cancer Hospital*). (The picture on the front cover shows a salivary gland cell of *Drosophila funebris*. Note the middle loop formed by two chromosomes whose pairing has been partly prevented by other chromosomes lying between them).

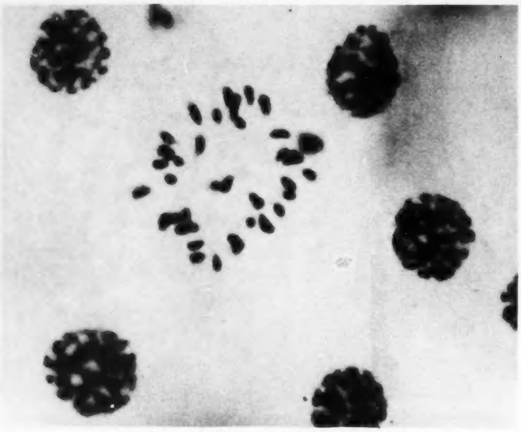


FIG. 4.—Mitosis in an erythroblast (red cell precursor) from the blood of a 12-day mouse embryo. 40 strongly spiralised and deeply stained chromosomes. Resting nuclei show heavy charge especially on the Feulgen-stained heterochromatin. × 2000.

Now in the ordinary resting nucleus the actively protein-producing parts of the chromosomes throw off their coats of nucleic acid. In doing so they become breakable by X-rays. But certain parts are frequently distinguishable by their reversing this process. In some tissues they are inactive and then acquire thicker coats of nucleic acid. These special segments, characteristic in position for each plant or animal, are described as composed of *heterochromatin*, and Caspersson has found some evidence that, when they are active, they are concerned in producing the smaller proteins while the rest of the chromosome, composed of *euchromatin*, is producing the larger globular proteins which would be expected to be more highly specific (Figs. 2 and 5). Certainly in the salivary gland nuclei the euchromatin appears as large specifically attracting chromomeres, while the heterochromatin, which in these nuclei is active, appears as small, not specifically attracting, chromomeres.

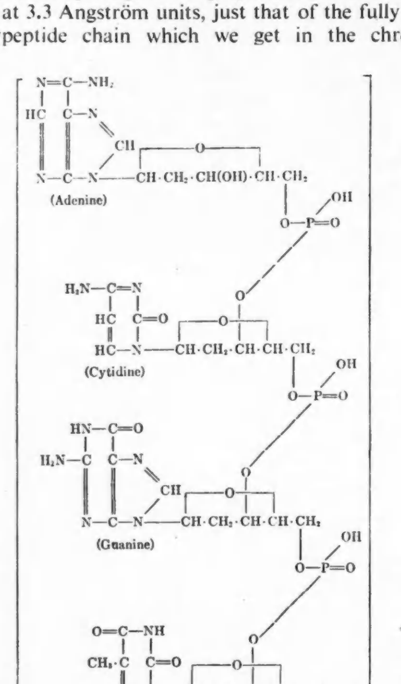
Breeding experiments, particularly with *Drosophila* and maize, have shown that in fact the euchromatin contains the highly specific genes which are responsible for the clear-cut differences used in demonstrating mendelism, in mapping the chromosome, and in the foundation work of genetics generally. The heterochromatin on the other hand, on the ground of the absence of such genes, was long thought to be inert. Extra chromosomes consisting wholly of heterochromatin are, however, present in many plants and animals which would certainly lose them if they were not doing useful work, as they indeed seem to be in some tissues, producing less specific proteins. There must then be a balance between heterochromatin and euchromatin that is best for each plant or animal. In the threadworm *Ascaris*, the dung fly *Sciara*, and the millet *Sorghum* some tissues have more or larger chromosomes than others. The germ track always keeps all the chromosomes. Other tissues lose some so that there must be a best balance for each tissue. In general, the heterochromatin seems to be useful, but unlike the euchromatin no part of it is indispensable.

The difference between heterochromatin and euchromatin can be used to test the functions, mechanical and physiological, of both kinds of nucleic acid. Many plants and animals will continue to undergo mitosis even at low temperatures. Near the freezing point, however, the nucleic acid attachment is liable to break down in a definite way. The heterochromatin is unable to get enough of the new charge; it is starved. During mitosis we then find the heterochromatin segments thinner than the normal and largely or entirely unstained (Fig. 1c).

The starved segments show two other abnormalities in extreme cases. First, they fail to coil up properly, remaining drawn out in fine threads during mitosis. Secondly, the halves of the divided chromosomes fail to come apart when they should: their reproduction or separation is somehow interfered with. Evidently nucleic acid plays a part, not only in coiling and uncoiling, but also in reproduction.

In the effect on coiling the nucleotide column is itself the physical agent. The contraction of muscle works with a similar molecule. The enzyme action of the protein, myosin, liberates phosphate from a ribose nucleotide. But here the myosin is the physical agent, while the nucleotide, it seems, merely serves to release chemical energy.

The effect on reproduction or separation we can likewise relate to other facts. In the first place, as Astbury has found, the spacing of the polymerised nucleic acid units was at 3.3 Angström units, just that of the fully extended polypeptide chain which we get in the chromosome



Chromosome Nucleic Acid (Greenstein 1944).

fibre. In the second place, as Caspersson has shown, the related ribose nucleic acid is bound up with protein formation everywhere in the cell save in connection with the chromosomes.

Wherever, as in the cytoplasm, the nucleolus, or the crystalline virus, protein production does not involve the permanent fibre structure of the chromosome, we find ribose nucleic acid alone. Its concentration is highest in the egg or young embryo, in the growing tumour, and in the secreting pancreas. In nitrogen-starved yeast it is at once increased by the supply of nitrate. In the egg, however, the ribose nucleic acid of the cytoplasm seems to be largely needed for conversion. It passes, presumably by way of the nucleolus, into the chromosome nucleic acid required by the nuclei which are to be produced in their thousands after fertilisation. Sometimes in preparation for this development in plants, a vast store of ribose nucleic acid is laid down in the nucleoli of the embryo sac cells. Elsewhere cells of various kinds act as nurse cells and provide the reserve for the developing egg.

Thus the two nucleic acids are mutually convertible and by conversion enable protein production inside and outside the nucleus to be kept in step. The conversion no doubt requires their splitting up into their constituent nucleotides for separate conversion and the later reconstruction of the large molecules. Inside the nucleus this evidently takes place very rapidly, less rapidly and only exceptionally outside it.

Whether by mutation or by crossing, plants and animals often come to have an extra amount of heterochromatin. The supply of cytoplasmic nucleic acid is then increased in the egg, and proportionately no doubt in sperm and pollen mother cells. Germ-cell formation at all stages depends on a nice adjustment of the nucleic acid metabolism and this upset may alter the timing of mitoses and even lead the cells to undergo extra mitoses. Pollen and sperm cancers, arising in this way, cause sterility. When, by an accident of mitosis, an increase of heterochromatin occurs in the body it will differentiate one cell from its neighbours in regard to growth rate. Such may be the cause of some types of spontaneous tumour. The ordinary processes of differentiation however, no less than mutation, separate cells with high and low nucleic acid contents. A particularly striking instance of this was found recently by La Cour in the differentiation of red and white ancestral cells, or precursors, in the bone marrow. The reds have a high content and their chromosomes are deeply stained (Fig. 4). The whites have a low content and show nucleic acid starvation. Unbalanced blood-cell formation follows when this nucleic acid differentiation is exaggerated, as in pernicious anæmia, or diminished, as in myeloid leukæmia. Thus we have in the staining of the chromosomes a simple means of studying the causation and development of many diseases of the blood.

The invention of such a convertible dual-purpose unit as the nucleotide was clearly one of the important chemical steps in evolution. But what effect has it had on evolution itself?

The specific hereditary properties of all plants and animals depend on specific properties of protein production. But evolution depends on changes in these properties. Such changes take place in the genes. If these molecules were lying about in the protoplasm of the cell their proportions would depend on chemical equilibrium. A change in any one group would change the equilibrium of the whole. This is the situation in the cytoplasm.

The chromosomes on the other hand provide a permanent physical framework on which genes are fitted and each one of these genes can be changed without affecting the qualities and proportions of the rest. The fibre structure of the chromosomes with its capacity for exact, proportionate and permanent reproduction makes it possible, as no other structure could, for the nucleus which they form to escape from the chemical equilibrium of the cytoplasm, and thereby to control this equilibrium and the whole cycle of heredity and development which depends on it.

We might therefore expect that (taking advantage of this position) all parts of the chromosomes would have become chemically and therefore genetically different. This is shown to be largely true in a variety of ways. There is first, as we saw, the difference in protein production and activity of the heterochromatin and euchromatin. There is also the constant association of genes identified by breeding experiments with particular places or "loci" on the chromosomes. And further there is the characteristic property we have already noticed in euchromatin genes of being indispensable. When a small piece of chromosome is broken off in the sperm by X-rays the egg it fertilises inevitably dies. And similarly when a few genes are reduplicated or repeated *en bloc* so that they occur in the chromosome in double dose the abnormal progeny are distorted in a direction which is specific for those particular genes. The "bar" mutant of *Drosophila* has its eyes reduced to a narrow band; it arises naturally in this way.

A large part of the "mutations" or heritable changes arising in nature are produced presumably by chemical changes within the genes which alter their properties of protein production. These changes must be of the type responsible for the origin of all the different genes from common ancestors in the course of evolution. We can get evidence of these changes from considering certain characteristic differences between heterochromatin and euchromatin.

The genes in the heterochromatin, as we saw, seem to produce smaller proteins (of histone type) while those in the euchromatin produce larger ones (of globulin type). The heterochromatin is therefore most active where the proteins produced are smaller, in rapidly growing, undifferentiated embryonic and tumour cells. The genes in the heterochromatin also have smaller and less specific effects than those in the euchromatin. On both these grounds heterochromatic genes correspond with the requirements of what the geneticist calls "polygenes", those genes which are of special importance in quantitative inheritance and are defined by Mather as having "small, similar and supplementary effects". The capacity for indefinite repetition within the chromosomes which this property implies again agrees very well with the older description of heterochromatin as inert.

In this light we are tempted to see (somewhat as Pontecorvo suggests) two main processes in the evolution of genes, by reduplication and differentiation, reduplication giving a repetition of small units, the polygenes, and differentiation giving larger co-operating units with more

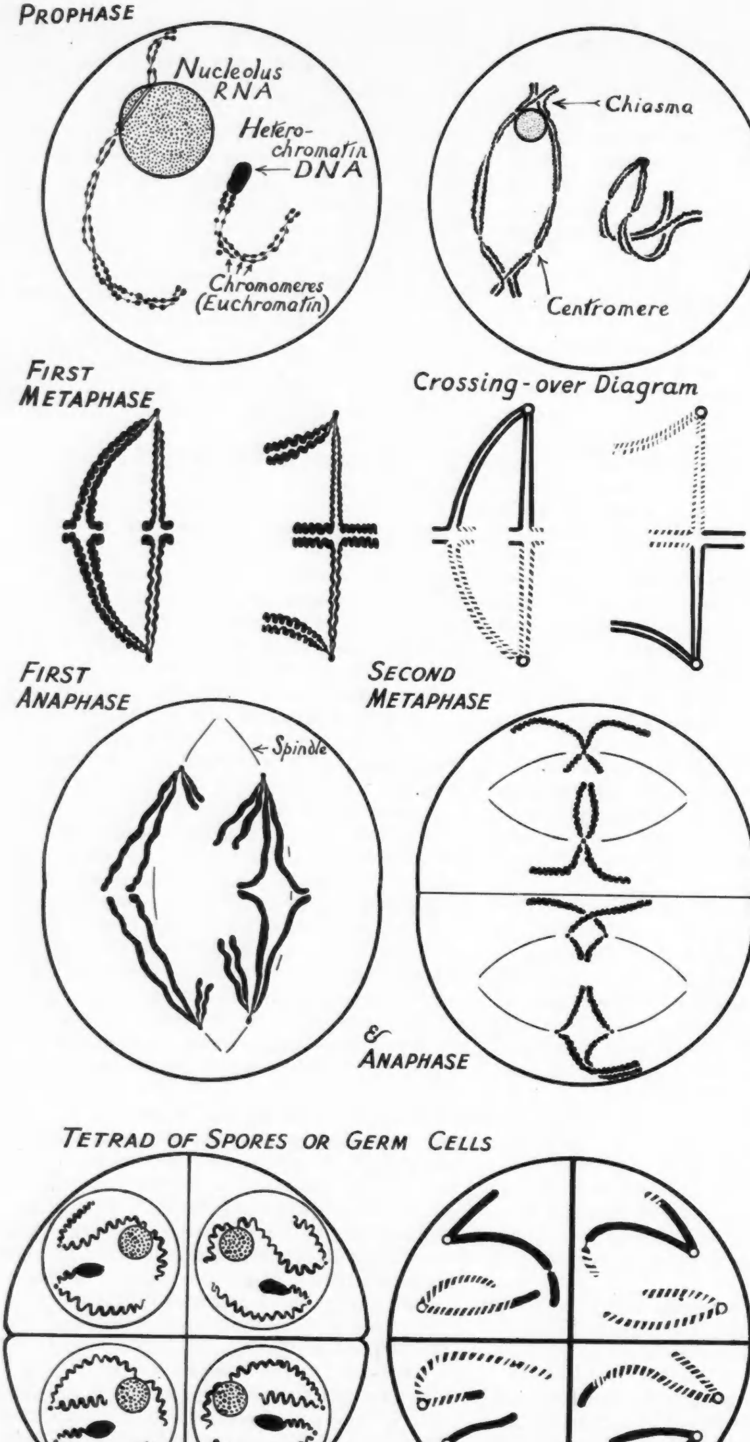
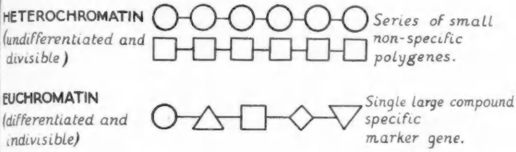


FIG. 5.—Diagram showing the structural history of meiosis in terms of two pairs of chromosomes and the genetic interpretation of the results in the tetrad of crossing over and segregation.

integrated action and larger molecular products which come into use as development and differentiation proceed. Diagrammatically we may represent the distinction as follows:



Between the nut-or-bolt level of organisation and the carburettor-or-dynamo level all intergradations would occur. Indeed we must say that in the physiological sense genes grow as they get older. In the euchromatin the co-operating chemical units would make one gene in action, and one chromomere in form, although capable of genetic change at separable points. In the heterochromatin the physiological units and chromomeres would be smaller and perhaps even unrecognisable as individuals. Which size of unit we take as our gene is of course a matter of convenience for the job on hand just as it is a matter of convenience whether we take the chromosome to be one molecule or many.

Now the differentiation of genes has no meaning apart from a second chemico-mechanical device, a second modification of the nucleic acid cycle of mitosis. This modification is known as *meiosis* (Fig. 5). It consists of two divisions of the nucleus combined with only one division of the chromosomes. There is therefore a reduction of chromosome number in the nuclei of the spores, sperm or eggs formed. In the testis the mitoses preceding meiosis follow a characteristic course. Successive mitoses show a higher and higher nucleic acid charge on the dividing chromosomes. They become more spiralised and hence thicker and shorter. In hybrids already at this stage the excessive charge leads to trouble in division. Normally, however, the crisis is reached at meiosis itself.

The first sign of meiosis is that the nucleic acid charge begins to be deposited on the genes before the materials are available for their reproduction and while they are still continuing active protein production. The result is that the resting stage is brought to an end by the chromosomes appearing as single threads and the genes (like those in the salivary glands) as separate "chromomeres" (Fig. 2E). And these chromomeres, being single, the attraction that they have for similar materials, which is satisfied in mitosis by reproduction, is now satisfied by attraction between identical partners. The homologous chromosomes from opposite parents (in a diploid with two sets of chromosomes) come together gene by gene in pairs. Thus all the visible threads come to be double, not by reproduction, but by pairing.

While the chromosomes are pairing they become further charged with the spiralising nucleic acid and coil round one another. With the accumulation of materials, reproduction eventually takes place and the chromosomes,

A

B

FIG. 6 (A).—Meiosis in a lily, showing the 12 paired chromosomes held together by 4, 5 or 6 chiasmata which make them look like chains of links. × 950.

(B)—Paired chromosomes in a lily, *Paris polyphylla*, ready for separation at first metaphase. Left: two arms with the centromere in the middle and two chiasmata in each arm. Right: one arm with the centromere at one end and two chiasmata in the arm. Note the spiral structure seen in optical section. × 1600.

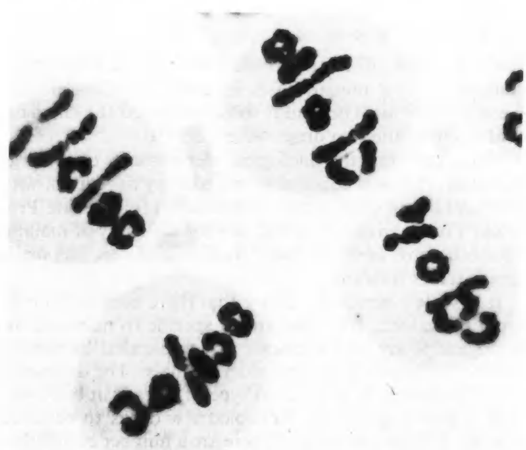


FIG. 7.—Smear of pollen mother cells of *Tradescantia bracteata* at first metaphase: fixed and stained with acetic orcein. Six pairs of chromosomes of which 3, 4 or 5 are ring-like with two or three chiasmata, the remainder rod-like with one. The variation is characteristic. × 900. (*Photograph by L. F. La Cour*).

now each of them double, repel one another and fall apart. But at the same time the new thinner threads are unequal to the coiling strain. At distributed points of greatest strain one of the four threads snaps. Each snapping leads to another snapping opposite to it. The broken threads, being released, uncoil and reunite to give a "crossing over" of parts of chromosomes in new combinations and a characteristic "chiasma" structure (Fig. 6). This in turn continues to hold the pairs of otherwise separated chromosomes together. Protein production may then be temporarily resumed (making up for previous haste). Two mitoses follow which effect the separation of the four threads. And at the end of the second mitosis there are four nuclei. All of them have the half or reduced number of chromosomes; all of them have different combinations of these chromosomes; and all indeed, owing to crossing over, have different combinations of parts of these chromosomes, that is of their constituent genes (Fig. 5).

Thus meiosis ensures an assortment of the dissimilar genes combined by sexual reproduction. And since the points of crossing over can be distributed in an endless variety of ways in the same individual, an endless variety of germ cells can be produced by it. Without such a recombination of genes, a combination of gametes is indeed meaningless. And since meiosis, with crossing over, is co-extensive with sexual reproduction in all animals, protista and plants ,we see that this simple device has been responsible for giving the chromosomes their capacity for combining permanence with impermanence: the permanence of heredity with the controlled impermanence of variation and recombination which is susceptible of selection, adaptation and therefore evolution. Meiosis has enabled the chromosomes to turn a chemical system responsible for one cellular organism into an evolutionary system responsible for all cellular organisms. And it has done this by a modification of the nucleic acid metabolism of the nucleus.

There are thus few aspects of general biology, whether the study of evolution, of plant breeding, of animal physiology or pathology, which are not bound up with the recent work on the chromosome nucleic acid system. And by the same means the study of heredity, development, and disease, long and necessarily separated, are brought back to their common basis in the cell.

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[*Continued from page* 78

Early samples of British mepacrine were submitted to clinical trial on human cases in close comparison with German atebrin. The results fully confirmed the chemical evidence that the two drugs were identical.

Since the war the biological department of a large industrial chemical concern in this country has set up, with the helpful and enthusiastic collaboration of the late Professor Yorke, an experimental unit for the study of malaria chemotherapy, and this, from small beginnings, has made rapid strides forward.

It has been mentioned above that there are four human types of malaria, but these are all specific to man and the biological study of the disease is complicated by the inability to transmit it to laboratory animals. The discovery, many years ago, of a malarial type of disease in birds was thus of great importance; it enabled new drugs to be tested first of all in the laboratory. There are a number of different types of malarial infections in birds, but the canary has been the most commonly used host in carrying out anti-malarial tests.

Early in the war, canaries were not being bred in sufficient numbers and canary seed was no longer available. A scheme for the supply of canaries was organised with the help of the Bradford and Shipley Budgerigar Society and run on a voluntary basis by the local secretary. This valuable and unusual piece of war-time work has produced a total of nearly 2,500 canaries in two years and has enabled rapid extension of the anti-malarial testing unit. In 1940-41 this unit consisted of one room and two workers only, but to-day it consists of a block of seven well-equipped laboratories with three experimental bird rooms, two large chicken houses (young chickens being now used in addition to canaries). It also possesses an insectarium for the hatching and rearing of mosquitoes which are used for transmitting malarial infections to birds in certain of the tests.

Some idea of the work being done in this unit is given by the fact that nearly a hundred canaries and about two thousand young chickens are being used per month in the testing of new drugs. Parallel with this and working in close collaboration with the biologists a team of research chemists are making and evolving theories as to the mode of action of anti-malarial drugs and the type of chemical configuration needed for anti-malarial activity. This will be of untold value in future work, and with the intense effort now being devoted to the problem, the discovery of new, better and safer drugs may not be long delayed.

Agricultural Research in the United States

F. RAYNS, O.B.E., M.A.

Director of the Norfolk Agricultural Station

THE foundation of agricultural research in the U.S.A. was laid by private individuals and organisations who, although primarily interested in other matters, found time for some agricultural investigation of a rather minor character. The first attempt by the Government to aid agriculture was made by George Washington. Washington, who was deeply interested in agriculture and farmed himself, found that his proposals for agricultural research did not meet with Government approval, and they had to be abandoned. However, despite this rebuff, the executive branches of the Federal Government took it upon themselves to encourage the introduction of pigs and sheep, silk worm eggs and mulberry cuttings—which were important at that time—and the seeds and cuttings of any plant likely to be useful. In 1810 a large number of Merino sheep were introduced from Spain, and in 1819 American consuls were officially requested to procure useful seeds and plants, but were instructed that "no expense can be authorised."

Soon afterwards agricultural interests were furthered by the agricultural division of the Patents Office, out of which the U.S. Department of Agriculture developed. The chief of the agricultural section of the Patents Office, one Isaac Newton, became in 1862 the first Commissioner of Agriculture. Much development followed; between 1840 and 1875 fourteen States established institutions for agricultural research; in the next thirty years fifteen other States set up experimental stations without Federal assistance, and fourteen others began to undertake agricultural experiments but did not immediately set up experimental stations. Ultimately each of the forty-eight States came to have a State Agricultural Experiment Station.

Finance

Much progress followed conferences in Washington in 1882 and 1883 on the work of agricultural colleges and experimental stations, and the conference report which was published by the Department of Agriculture led to the passage of the Hatch Experiment Station Act of 1887, and the Morrill Land Grant College Endowment Act.

These Acts made possible the establishment of the Land Grant Colleges, as they were termed, and stimulated such rapid development that at the beginning of the 20th century the agricultural experimental stations became the victims of their own success. Increased demands for advice and education absorbed so much of the Hatch fund for administrative purposes and for the preparation and distribution of publications that little was left for research. In 1902 therefore, the need "for larger and more thorough experiments in many lines" was urged, and in due course its recognition resulted in the Adams Act which provided further Federal funds for the agricultural experimental stations[1].

Later came the Purnell Act and the Bankhead Jones Act. Under the Hatch, Adams and Purnell Acts the state colleges receive annual grants of \$15,000, \$15,000 and \$60,000 per annum under each Act respectively towards the work of experimental stations; the Bankhead Jones appropriation is made upon a per capita basis of the state population. The states themselves raise money for state purposes including, of course, agricultural education and research. Public funds, therefore, are drawn for these purposes from two sources—the one state, the other federal.

State agricultural experimental stations receive their grants through the state university when their parent agricultural college is part of the university; otherwise the grant is paid direct to the state agricultural college by the Federal Government. Further income for agricultural research is obtained from endowment fellowships and commerce. The income of the Minnesota Experiment Station provides a good example of the various sources of revenue[2]. This is one of the larger experimental stations of the U.S.A., and its income for 1942 was as follows:

		Dollars
Federal Appropriation	Hatch Fund	15,000
	Adams Fund	15,000
	Purnell Fund	60,000
	Bankhead Jones Fund ..	57,269
State Appropriation	General University support ..	263,294
	Special appropriation ..	49,088
	Endowments, etc.	28,121
	Fees, sales and miscellaneous	24,847
	Total	\$512,619

About £125,000 is allowed therefore to meet the needs of an area of 84,000 square miles and a population of 2,800,000, only a proportion of whom are engaged in agriculture.

There is one further source of income which seems to be accepted more readily in the U.S.A. than in Britain, viz.: that from commercial interests. A firm wanting research done on some problem relating to their product may request the U.S. Department of Agriculture or a particular state experimental station to undertake the investigation. The firm is invariably willing to meet all expenses. In 1938, for instance, the American beet-sugar industry granted \$80,000 over a five-year period for research work into the possibilities of completely mechanising the cultivation of sugar-beet, and has since increased the grant by another \$20,000. This was a bold and ambitious project. The university or college, however, exercises considerable discrimination in its choice of "co-operators", as they are termed, in the agreement between the two parties, and stipulates that no commercial brands or trade names shall appear in the publication of the results, nor shall the name of the university be used for advertising

[1] *A History of Agricultural Experimentation and Research in the United States Department of Agriculture*, 1937.

[2] *49th Annual Report, Agricultural Experiment Station, University of Minnesota* (1941-42).

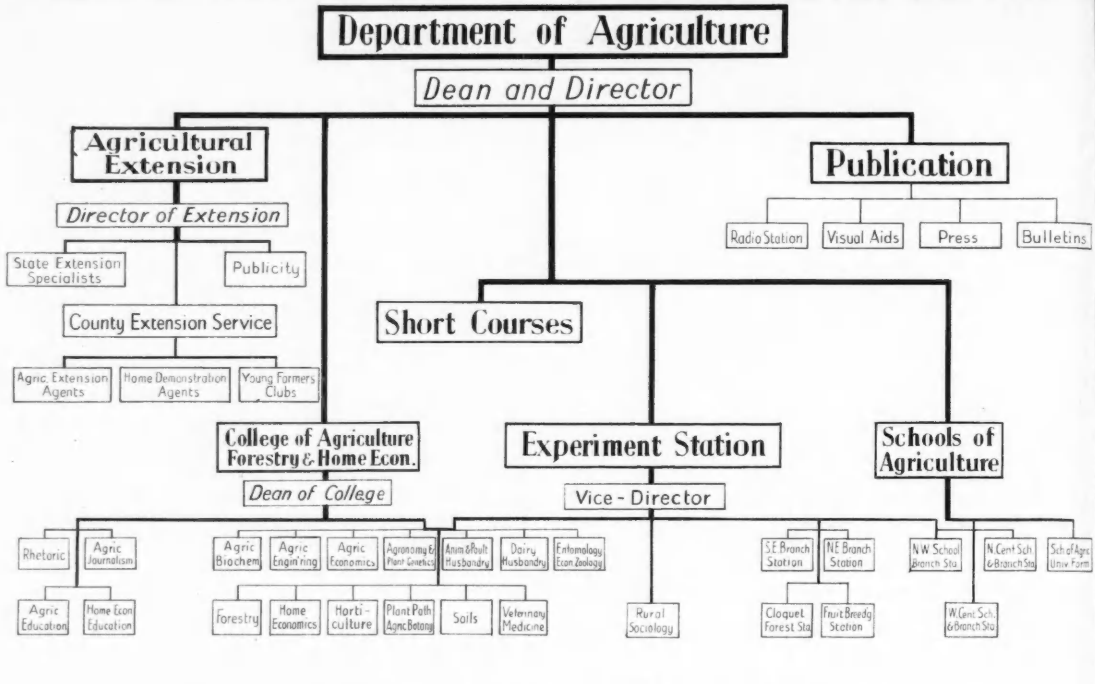

Chart showing the Organisation of the Agricultural Department of an American university.

purposes. The university also reserves the right to publish the results.

Organisation within the State

In each state research is mainly centred on the State Agricultural College, and is carried out by the State Experiment Station which is part of the college. The Experiment Station often establishes sub-stations to study the problems connected with a particular soil or particular type of farming. Occasionally, the work of teaching as well as research is partly decentralised. Minnesota provides a good example. This state has an agricultural college attached to the university, a college farm and experimental station, all being situated at St. Paul, and five regional sub-stations which are fully equipped both for teaching and research; each sub-station in normal times instructs about 400 resident students. There is however, no hard-and-fast rule. Michigan provides a contrast. The whole of the state agricultural teaching is done at the state agricultural college, and although Michigan has sub-stations for research and demonstration purposes there is no teaching at the sub-stations; nor is the Michigan State College connected with a university.

The university or college president is usually the senior member of the agricultural staff, but the administrative head is the dean of the Department of Agriculture, who may also act as the director of the Experiment Station; there is often a separate director of the Experiment Station and of the Extension Service—the service concerned with getting the results to the agricultural community.

The overall pattern is much the same, however, in all the states and the general picture is well illustrated by the diagram showing the organisation of agricultural department at a particular American university.

The diagram shows the Dean of Agriculture as head of the Department of Agriculture, the Extension Service, and the Departments of Forestry and Home Economics—an arrangement that will commend itself to those who believe in unity of command, in co-operation and co-ordination. Particularly, perhaps, to those who feel that a research worker is not necessarily an inspired genius who must be left to his own resources free to take only the path his mind dictates, but rather one who can be assisted by helpful direction and fitted, when needed, into a team of workers attacking the same or related problems. The diagram also illustrates the sub-division of the State Agricultural College into departments, each with a divisional chief conducting research work in the division's particular field; it shows, too, the further breakdown into the regional sub-stations, each designed to deal specifically with the problems of its district.

Influence of the Federal Government

While the state agricultural colleges are to a great extent autonomous, the Federal Government approves all projects in which federal funds are to be used. The

Department of Agriculture in Washington has in fact its own comprehensive organisation for education and research, and not only oversees the research work done in each state, but itself participates in research work on problems of national rather than state importance.

The Department of Agriculture is charged by Congress with the duty of "acquiring and diffusing among the people of the United States information on subjects connected with agriculture in the most general and comprehensive sense of that word"—the quotation is from Miscellaneous Publication No. 431 of the Department of Agriculture. The Department has many other activities in addition to conducting research and extension work. It administers numerous federal laws relating to agricultural adjustment (mainly controlled production), soil conservation and land use. It also deals with loans to farmers for capital and working expenses, flood control, farm tenancy, rural electrification, rural rehabilitation, protection and management of national forests, crop and livestock disease and pest control, to name only a few. Thus the Department has five different types of activities: *research*, *planning*, *education*, *action* and *regulation*. For these purposes it has thirty-one major departmental units. Of these at least nine undertake research as a major function. They are the Agricultural Marketing Service, the Soil Conservation Service and the following Bureaux: Plant Industry, Agricultural Chemistry and Engineering, Agricultural Economics, Animal Industry, Dairy Industry, Entomology and Plant Quarantine, Forest Service and Home Economics. The head of each department is a fully qualified technical officer frequently recruited from the staffs of state agricultural colleges or others who have had actual experience outside the Government offices at Washington.

The Secretary of Agriculture exercises general control over all the Department's affairs and is, of course, assisted by a very large staff. Research is administered by the Office of Experiment Stations, an important function of which is to make disbursements under the Hatch, Adams, Purnell, Bankhead Jones and certain supplementary Acts. The Office of Experiment Stations is a part of the Office of the Secretary, and its head is known as Chief of the Office of Experiment Stations and Director of Research. His is indeed a great responsibility, for his department not only controls the purse strings of federal agricultural research but coordinates and fosters co-operation in research between the various federal research bureaux, between the various state experimental stations, and between the state experimental stations and the federal bureaux. Thus the Office of Experiment Stations receives and considers all proposals for co-operative research involving federal expenditure, and collects and disseminates information likely to assist research workers; much of the latter is given in summary in the *Experiment Station Record*—a familiar and valuable publication known to agricultural research workers the world over.

The Department itself has a special research fund which is devoted to particular research projects of national rather than state importance. These may be carried out at the federal experimental station at Beltsville near Washington, D.C., or at other federal stations in the major agricultural regions.

Considerable progress has been made by federal and state co-operation in agricultural research. To give but one example: America has a very large pig industry, and pigs and pig improvement are particularly important especially in the Corn Belt states like Iowa, Illinois, and Minnesota. To further pig improvement a national swine laboratory was set up in Iowa, the leading pig-producing state, at the state agricultural college. The national laboratory, from its centre in the middle of the industry, co-ordinates work on similar lines at other state colleges. A few years ago those responsible for the improvement of the American pig industry decided that none of the native pigs entirely met the needs of the industry in such points as conformation, fecundity or their capacity to withstand the hot conditions of the American summer. The national laboratory, and the co-operating state laboratories therefore started to breed a new type of pig. The work is now nearing completion, and promising new types of pigs have been bred. Similar co-operation exists for work on the improvement of maize and other cereals, lucerne and other forage crops, and for investigation into sugar beet mechanisation, plant breeding, the use of fertilisers and so on.

The staff required for this co-operative work is provided by both the Federal Government and the states. When necessary the Federal Government places its outstanding workers at the appropriate state college.

Some of the Problems

The U.S.A. has still to provide the answers to vital questions on agricultural development. In our more settled agriculture there is less developmental work of a pioneer character to be done. We have a long experience behind us. But within the memory of living man the farmers in some parts of the United States have started, from virgin prairie or woodland, to establish their farms. In this process there has been much misguided effort, and not a little exploitation. As time passed the U.S. Government had to take a hand in devising better methods of farming. The improvement of natural range grazings by better management; the selection and breeding of improved herbage plants for the dry arid areas, where one Hereford cow and her calf are often the only stock on fifty acres of the original herbage; the extension of the Corn Belt; the breeding of corn strains specially suited to the climate of particular states—these are all examples of research work still intimately and primarily concerned with the settling-down process of United States agriculture. British research workers are but rarely called upon to undertake this sort of work. The best comparable example of recent times is probably the establishment of British sugar-beet industry, which received much assistance in its development from the British Sugar Beet Research Committee.

The mistakes of the U.S. pioneers have also had to be rectified. Inappropriate farming, some of which was nothing more than blatant exploitation, resulted in catastrophic losses from soil erosion, and a special service —the Soil Conservation Service—was established with the aim of trying to prevent further loss and for the purpose of investigating and advising on the best methods to

combat soil erosion. It is a very comprehensive national organisation set up for one very vital object, in which research is an essential feature.

It would be unfair, however, to the great body of research workers in the U.S.A. to give the impression that all their work is concerned with the development of a pioneer agriculture. That is not so. The amount of fundamental research work of the kind we associate with the Rothamsted Experimental Station, the Rowett Institute, or the School of Animal Physiology at Cambridge is legion in the U.S.A., and adds daily to the world's fund of agricultural knowledge.

The research stations are excellently equipped and well built; they are often sited in the University or College campus in beautiful surroundings. Most of the animal husbandry stations have their own abattoirs and refrigerators, and are in a position to make studies on the end product of their research, be it beef, mutton, pork, bacon, or wool. Similar provision is made in other branches. Research workers may even broadcast the results of their work by wireless, for a number of universities and some state colleges have their own radio stations and run a daily farm programme.

Farming as a whole in the United States is refreshingly free from the shackles of tradition. The farmers have had to rely upon their own and other farmers' experience, and upon the state agricultural college and its experimental stations. It has produced extensive co-operation and engendered an admirable spirit of farming adventure, in practice and especially in research.

The R.A.F's Gyro-Magnetic Compass

THE Distant Reading Compass, upon which to a large measure depends the accurate navigation of planes of the Allied air forces, came off the secret list only last month, yet the basic conception of this instrument dates back more than ten years. Credit for the first tentative ideas from which it was developed belongs to members of the staff of the Royal Aircraft Establishment at Farnborough; in this connection may be mentioned the names of Mr. P. A. Cooke, Mr. C. B. Stewart and the late Mr. L. Bygrave. A prototype was tested in a series of stringent flight trials at Farnborough which established that the compass would operate under conditions where ordinary compasses could not be relied upon or would not function at all. In 1937 the prototype was sent to an industrial firm, the Automatic Telephone and Electric Co., Ltd., of Liverpool, and a further period of three years was spent developing the instrument to the pitch of perfection necessary before it could be fitted to operational aircraft.

The requirements that the D.R. Compass fulfils are the conditions that it must not be affected by rapid acceleration or deceleration, by steep turns or other manoeuvres. Ordinary magnetic compasses are useless under such conditions, since they are unstable with varying air speed or course and are sluggish or inaccurate when located near armour plating in or around the pilot's cockpit. An aircraft can only be steered by an ordinary compass while the plane is being flown on a straight and level course. In the early days of the war a pilot had to fly straight and level for two or three minutes every quarter of an hour or so while the compass needle steadied and an adjustment could be made between it and the gyroscopic direction indicator (that showed continuously the heading of the aircraft). The most dangerous minutes of a raid used then to be at the end of a bombing run, when the pilot had to carry out this procedure in the target area, exposed to flak and fighter attack; to-day, after the bombs have been dropped, the pilot can turn immediately for home, relying upon the accuracy of the D.R. Compass.

The gyroscope that is built into the instrument, possessing great "rigidity" in space on account of its high speed of revolution, remains pointing to a pre-set position despite any relative movement of its outer case, and so provides a fixed datum line by which changes of course by the aircraft can be measured; such changes, resulting in a corresponding change in the angle between the gyroscopic axis and the fore-and-aft line of the aircraft, are registered by the master compass which actuates an electrical transmission system by which every change of course is relayed to repeater compasses located at the various crew positions throughout the aircraft. The compass is also utilised for operating bomb sights and automatic pilots. A variation setting corrector is also incorporated in the compass installation and enables local magnetic variations up to 30° E. or W. of true N. to be allowed for. The electrical harness linking the master compass, repeater compasses, etc., are screened to eliminate interference with radio or other electrical systems of communication.

The attack made by Lancasters on the diesel-engine works at Augsburg in the spring of 1942 is an example of a raid which dead accurate navigation was essential, to which the D.R. Compass contributed much. The breaching of the Mohne and Eder dams in May, 1943, was another instance, as were also the Fortress raids on the Ploesti oilfields.

One interesting sidelight concerns the testing of this compass. For the last five years all D.R. compasses have been tested in an inconspicuous suburban house in Edge Lane, Liverpool. This work was originally done in the main A.T.E. factory, but it was found that owing to the presence of steel in the building structure stray magnetism caused slight interference with tests. Hence the house in Edge Lane where even the nails in the floors were taken out and replaced by non-magnetic material.

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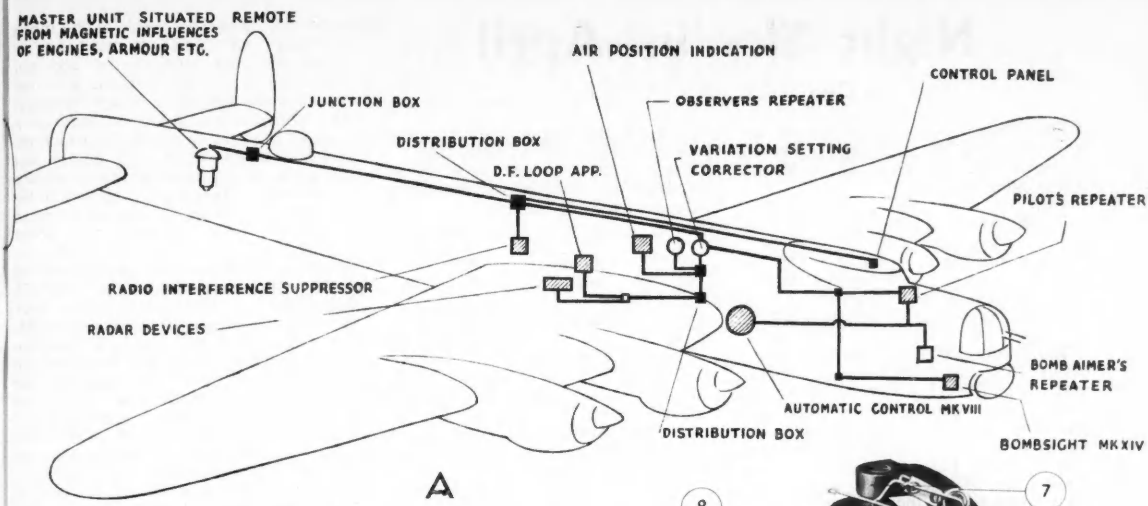


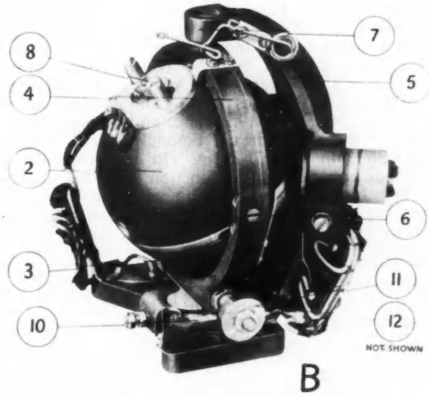
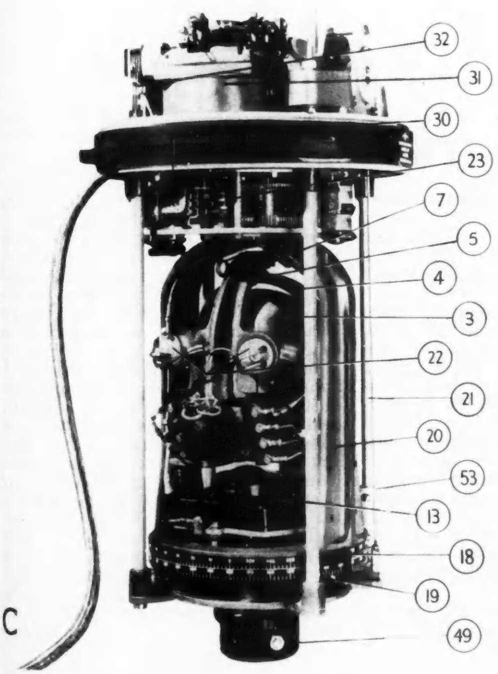
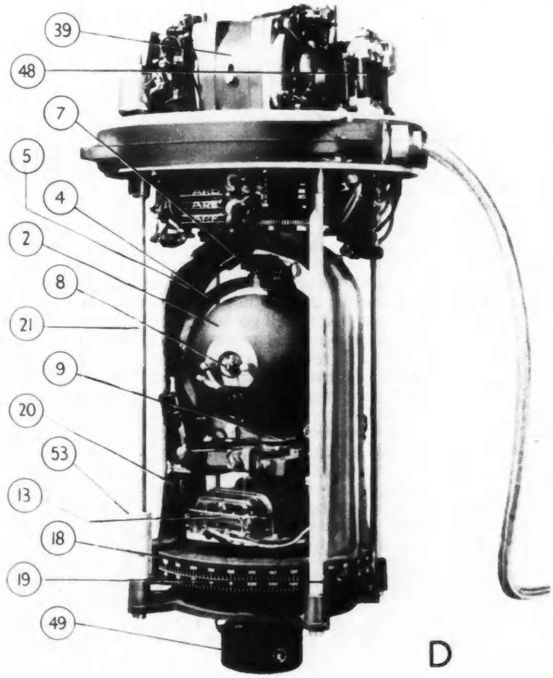


FIG. A.—The diagram indicates the location of the master compass in the tail of the aircraft; the readings of this instrument are transmitted electrically to repeater compasses situated at the various crew positions. The master unit also exercises some control on the bombsight, automatic pilot and master radio equipment.

FIG. B.—The gyroscope component. The fixed half (2), pivoted to the inner ring (4) by screws, forms the stator of a 3-phase squirrel cage motor, power for which is provided by a rotary converter (39, Figs. C and D); the aircraft's 24-volt D.C. supply drives it at about 3000 r.p.m. The free half (3), a metal dome with a very high electrical conductivity, acts as the rotor of the squirrel cage motor, revolving clockwise at about 12,000 r.p.m.; this high speed gives the gyroscope great stability.

FIGS. C & D.—Two views of the D.R. Compass with cover removed. It consists essentially of a small accurately constructed gyroscope (2 and 3), a north-seeking magnet (13) and an electrical transmitter (30) by which displacements in terms of the heading of the aircraft are transmitted to the various repeater compasses.





Night Sky in April

M. DAVIDSON, D.Sc., F.R.A.S.

The Moon.—New moon occurs on April 12d. 12h. 29m. U.T., and full moon on April 27d. 10h. 33m. The following conjunctions take place:

April				
9d. 19h.	Mars in conjunction with the moon	Mars	3°	N.
17d. 13h.	Saturn ,,	Saturn	0.1	N.
23d. 06h.	Jupiter ,,	Jupiter	3	S.
26d. 18h.	Mercury ,,	Mercury	6.3	S.

The Planets.—Mercury rises at 5h. 49m., about 13 minutes after the sun, on April 1, and sets at 20h. 11m. At the end of the month the corresponding times are 4h. 10m. and 17h. respectively. The planet is in inferior conjunction with the sun on April 13, and is stationary on April 3 and 25. Venus rises at 5h. 26m., 10 minutes before the sun, on April 1, and sets at 21h., being a conspicuous object in the western sky. At the middle of the month the times of rising and setting are 4h. 24m., and 19h. 18m., and at the end of the month the corresponding times are 3h. 35m. and 17h. 23m. On April 15, Venus is in inferior conjunction with the sun. Jupiter sets at 5h. 13m. on April 1 and at 3h. 14m. on April 30. The planet's distance from the earth between these dates varies from 418 to 442 million miles.

If there is any doubt about identifying Jupiter, its times of crossing the meridian will assist; these are, 22h. 46m., 21h. 46m., and 20h. 44m. at the beginning, middle, and end of April, respectively. Saturn sets at 1h. 49m. and just after midnight at the beginning and end of April, and will soon be badly placed for observation. Between these dates the distance of the planet from the earth varies from 845 to 887 million miles.

Times of rising and setting of the sun and moon are given below, the latitude of Greenwich being assumed:

April	Sunrise	Sunset
1	5h. 35m.	18h. 33m.
15	5h. 06m.	18h. 56m.
30	4h. 34m.	17h. 21m.

April	Moonrise	Moonset
1	22h. 32m.	7h. 25m.
15	7h. 04m.	23h. 03m.
30	22h. 37m.	6h. 20m.

Meteors.—The Lyrid meteor shower is active from April 18 to April 22, but moonlight will interfere with the observation of the meteors. These meteors are caused by the debris of Thatcher's Comet (1861), which is spread round the orbit of the comet and which the earth encounters each year from April 18 to 22.

Easter occurs on April 1, and something about this festival may interest a number of readers who are uncertain why it varies so much—its date can vary as much as 35 days in different years.

Easter is defined by the Church as the Sunday which follows the full moon falling on or next after March 21, but if the full moon falling on or next after March 21 happens on a Sunday Easter Day is the Sunday after.

This system of keeping Easter implies considerable oscillation in the date of the festival, and certain complications ensue owing to the fact that the moon which is used for determining Easter is not the actual moon of the heavens but a conventional moon which can be adopted anywhere. When we speak of the moon as "new" or "full" it must be remembered that such terms are not applicable everywhere because they depend on the longitude of the observer. This conventional moon depends on a cycle of 19 years, at the end of which the sun and moon return very nearly, but not quite, to the same positions relative to the earth. This cycle is known as the Metonic cycle, after Meton, an Athenian astronomer who discovered it about 433 B.C. To show how close the coincidence is it may be noticed that 19 Julian years are 6939d. 18h., and 235 lunations are 6939d. 16h. 31m. 14s. This small discrepancy is not responsible for much difficulty; the chief complications arise from the fact that the odd day at the end of the year implies that the Sundays in successive years occur on dates earlier by one day and, in addition, on leap years they fall two days earlier after February 28. As a consequence the Sundays will not return to the same dates till the expiration of 28 Julian years, so that the complete cycle for Easter, according to the Julian system, is $19 \times 28 = 532$ years. Under the reformed calendar of Gregory certain corrections to this system of finding Easter were necessary, and tables showing how to make these are found in the beginning of the English Book of Common Prayer. These tables were compiled by Bradley, Astronomer Royal, when the reformed calendar was adopted in England in 1752. It would take too long to explain these tables in detail, and readers must be content with the above brief explanation about the method of determining Easter. There is much to be said in favour of fixing the occurrence of this festival within narrow limits but there is opposition in certain quarters, and it may be some time before any scheme which has been suggested will be universally adopted.

JUNIOR SCIENCE

Lighting a Fire

ALL of you will have experienced the difficulty of lighting a fire, and you all know only too well that a fire which can be lit with just one match has to be "built" carefully. On the other hand, once the fire is going and the coal is burning well, we need not fear that it will go out again. In fact, an effort is needed to extinguish a fire as long as there is still combustible material on it. These observations have become so much an everyday experience that they do not surprise us. Nevertheless it is rather astonishing that a heap of fresh coal, full of combustible material, should burn less well than the same lot of coal after it has already lost half of its fuel through having burnt for a while.

The reason is that it is not the coal or the wood in a log which burns but quite different substances—fuel gases—which are only developed when coal or wood is heated. In fact, if this were not so, we could not store fuel like coal or wood. For combustion is merely a chemical reaction of the burning substance with the oxygen of the air, and if coal were to react directly with air we could not keep it indefinitely in the coal cellar since it would go on oxidising. Thus, to light a fire we must first generate the necessary heat for the development of the fuel gases. And that is where the "building" of the fire comes in. The amount of heat generated by burning a match, if applied directly to a lump of coal, is quite insufficient to heat the coal to the temperature that is necessary for the production of the gases. We must therefore first light a more "inflammable" substance, such as a piece of paper or some fire-wood, which will liberate some fuel gas upon the application of a burning match. In your house fire-lighters may be used, and these are prepared from substances which exhibit this property of "inflammability" particularly strongly.

Once the solid fuel has been set burning, the combustion of the fuel gases, that means their oxidation by the surrounding air, provides sufficient heat not only to warm us but also to go on liberating fresh fuel gas from the burning lump of coal. The energy needed to expel the gases which will have to be burnt is thus provided by the combustion process itself, and the process will only cease to function when the supply of fuel gas contained in your lump of coal is exhausted. You can watch the liberation and combustion of fuel gases in any ordinary coal fire. When a fresh lump of coal or a log has been on the fire for a little while you will often see a flame, sometimes more than an inch long, spurt out, rather like a jet of coal gas. What has happened is that fuel gas has been liberated inside the coal by the surrounding heat, building up a pressure until eventually the gas is expelled and escapes through some crack. It begins to burn as soon as it reaches the surface where it meets the oxygen of the air.

K.M.

The Bookshelf

High Frequency Transmission Lines. By WILLIS JACKSON. (London, Methuen, Monographs on Physical Subjects, 1945; pp. vi + 152; 6*s*.).

THIS book is an example of the "concentric" treatment of a subject: the first chapter makes a rapid circuit of the various applications of transmission lines at high radio frequencies, and after thus arousing the reader's interest the author proceeds to a detailed quantitative analysis of the characteristics of lines. The chapter on "Basic Equations" shows the relationship between the transmission line equations and Maxwell's equations; and the relationship with single-conductor "wave-guides" is brought in as a means of estimating the extent of the local field disturbance arising from discontinuities in the line. The only criticism of this chapter is that these equations are not the most attractive example of the use of M.K.S. units, for we have to be reminded that "the permittivity of free space (air) $= 1/36\pi \times 10^9$". One would have thought the engineer would have preferred to use c.g.s. units, making the permittivity and permeability of free space equal to unity, rather than use M.K.S. units in order to eliminate a constant factor from one of Maxwell's equations; and surely no physicist, after being so meticulous in securing symmetry in the equations of radiation, would have referred to "free space (air)". (The varying permittivity of air is actually an important factor in the propagation of U.H.F. radio waves beyond the optical horizon). The principal concern of this book, however, is with the behaviour of lines when first the length and then the spacing between conductors is of the same order of magnitude as the wavelength of the applied frequency. While the spacing is still small compared with the wavelength, junctions and other discontinuities in the line need not be considered in microscopic detail; one can terminate a line with an appropriate resistance, use a quarter-wave section of line as an impedance transformer and use appropriate lengths of line as reactances. All these applications, including the use of "stubs" for matching load to transmission line, are thoroughly examined and the technique of measuring the magnitude and phase of a terminating impedance in terms of standing-wave patterns is explained. At still higher frequencies, when the *spacing between conductors* in the line becomes comparable with the wavelength, the wave-guide modes of propagation become significant, and the detailed geometry of the terminations and junctions has an appreciable influence on the field distribution in the line; the mathematical treatment of this condition is in general discarded in favour of experimental adjustments. Professor Willis Jackson has elsewhere made a valuable contribution to the "circle diagram" method of solving transmission line problems, and this book explains the construction of both cartesian and polar forms of diagram, which are of great help in designing ransmission line systems to meet specific requirements.

D. A. BELL

The Measurement of Colour. By W. D. WRIGHT. (London, Hilger, 1944; pp. 220, 30*s*.).

DR. WRIGHT'S book sets out to describe what can, and what cannot be done in the way of measuring colour, and not only does it do this admirably but it also answers the question how to, and how not to, and has something to say on why colour should be measured scientifically in the first place.

Colour is such an everyday feature of life that all too frequently when a question of colour standardisation or measurement crops up in a new situation it is thought to be a very simple problem, whereas in fact the field is liberally mined with booby traps of many sorts. Dr. Wright guides the reader round nearly all of these, without omitting to point out their existence.

The scope of the book is wide, covering the structure of the retina, the mathematical and physical basis of the trichromatic system of colour measurement, the design and use of various types of colorimeter and spectrophotometer, the nature and purpose of "colour atlases", and includes a discussion of a number of common industrial applications of colorimetry.

For those whose interest is less severely practical the book provides an excellent summary of much of the physical data on colour vision, including recent work on the sensitivity of the eye to small differences in colour. The data are presented without bias towards any particular theory of the physiological mechanism involved and consequently the book is a much more suitable introduction to the subject than the majority of more popular works, most of which begin by describing one of the many theories and then present only such evidence as agrees with it.

It is a great pity that a better quality of colour printing has not been used in the diagrams, but no doubt this and the high price must be attributed to present conditions of book production.

C. G. A. HILL.

British Botanists. By JOHN GILMOUR. (London, Collins, 1944; pp. 48, 8 coloured plates + 19 black-and-white illustrations; 4*s*. 6*d*.).

British Botanists, one of the latest additions to the well-known "Britain in Pictures" series, is attractively written and lavishly illustrated in colour and in black-and-white. The book traces the development of British botany from Tudor times to the present day, wisely omitting any survey of the work of living botanists. The very substantial contributions to the science of botany made by British workers are briefly but sufficiently described, enough being said of the work of botanists of other countries to show that botany, as is science in general, is an international affair. The actors in the scene appear as human beings, some likeable, some not; they do not appear as remote scholars immersed wholly in their studies and exempt from the weaknesses of the ordinary man; that is how they were, for they were men before they were botanists.

The author of *British Botanists* is the assistant-director of the Royal Botanic Gardens, Kew; it is not surprising therefore that the influence of Kew upon the development of British botany receives, rightly, marked attention, or that the systematic aspects of the subject are very much to the fore. But, attention is drawn to other lines of work now open or opening, and maybe it will fall to the lot of Mr. Gilmour to foster the growth of botany along those lines.

It is a matter for some regret that various points of detail are not altogether satisfactorily presented, in particular those which refer to the physiology of plants; the fundamental importance of respiration as a source of energy is overlooked, and the unique power of the green plant to make its food from the simple substances taken from the soil and the air is not explained clearly; mineral substances, carbon dioxide and water—the substances from which foods are made—are not themselves foods in the strict sense.

But the book is addressed to the general reader rather than to the professional botanist; to the general reader, *British Botanists* cannot fail to reveal the worthiness of botany as a study. The book whets the appetite, and incidentally brings out a great defect in our scientific literature, the absence of an up-to-date, authoritative and acceptable full-length study of the history of botany, both here and abroad. Maybe, among the various post-war improvements for which we hope, there may be the institution of fellowships to enable a few suitably qualified scholars not only to practice and nurture their special subjects, but also to give in due time comprehensive and informed historical surveys of their chosen fields. It is very undesirable that the past should be neglected.

British Botanists sent the reviewer to re-read Kipling's *Fairy Kist* and to revive memories of *Mary's Meadow* for it is a working in the same vein as those very human stories. We need, and that not only in these troubled times, a strong tincture of humanity in our science.

B. BARNES.

The Caterpillars of the British Butterflies. Compiled by W. J. STOKOE; edited and with special articles by G. H. T. STOVIN. pp. 248; 348 illustrations. (Frederick Warne, 1944; 10*s*. 6*d*.)

THIS book, the latest addition to the Wayside and Woodland series, is a companion volume to South's *Butterflies of the British Islands*. It covers all the British species. A feature is the illustrated list of food plants on which eggs and caterpillars are found.

Far and Near

History of War-time Science

THE Scientific Advisory Committee to the British Cabinet has appointed an archivist under whose guidance all government departments are working to ensure that records of scientific war work are preserved. Before the scientific staffs of the various departments have been dispersed suitable monographs will be written to supplement these records.

The announcement of this appointment recalls a passage from a recent letter which President Roosevelt sent to Dr. Vannevar Bush, director of the U.S. Office of Scientific Research and Development: it reads, "What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions which have been made during our war effort to scientific knowledge? The diffusion of such knowledge should help us stimulate new enterprises, provide jobs for our returning service-men and other workers and make possible great strides for the improvement of the national well-being".

DISCOVERY recommends this utterance to the attention of the Scientific Advisory Committee, for the story of Britain's scientific achievements during the war deserves to be told widely and fully; it would be unfortunate if it were reserved for "archives". An official history of British war medicine has been underway for many months; is it too late to consider the compilation of an official history of war-time science?

Tax Relief for Scientific Research

IN the last Budget speech the Chancellor of the Exchequer promised tax relief to industrialists in regard to expenditure on research and certain other items. The promise is given effect in the new Income Tax Bill, details of which were announced last month. The existing allowance for scientific research expenditure is extended to payments made after April 6, 1944: an allowance will also be made for capital expenditure on buildings, plant and machinery for research incurred after January 1, 1937. An annual allowance spreads the cost of new patent rights, acquired after "the appointed day" referred to in the Bill, over 17 years or the life of the patent if shorter: the seller of the patent will be charged to tax, the charge being spread over 6 years. Provision is made for earlier writing-off of patents sold or lapsed.

Underground Gasification

THE Minister of Fuel and Power stated last month that the Fuel Research Station and the Geological Survey are studying the possibilities of underground gasification in order to determine whether geological and other conditions in Britain would justify experimental trials of the process. He added that the Ministry had received a great deal of Russian literature on the subject, all of which had been translated.

Penicillin by Mouth

To attack bacteria by means of chemical agents such as sulphonamides or penicillin it is necessary to bring the drug in contact with all the bacteria in concentrations high enough to inhibit their growth. To reach deep-seated infections that are not accessible to local applications, it is necessary to introduce the drug into the blood, which carries it to all parts of the body. Sulphonamide drugs are in general readily absorbed from the intestinal tract, and can therefore be conveniently given by mouth. However, this method has up to the present proved impracticable with penicillin, for, although there is evidence that it can be, at least partially, absorbed from the intestines most of it is destroyed by the acid gastric juices. A number of attempts have been made to overcome this difficulty. One method has been to give sodium bicarbonate simultaneously with the penicillin, with the object of neutralising the acidity of the stomach, but results have not been satisfactory. In 1943 a method was tried in which the penicillin was enclosed in a capsule designed to carry it through the stomach and liberate it in the duodenum; the capsule was coated with cellulose acetate phthalate, which is soluble in alkali but not in acid. Only limited success was obtained, partly due to the uncertain bursting of the capsule, which was sometimes delayed as long as six hours. It is now reported that similar "penicillin pills" are being made in the United States. These capsules are said to have an outer coating of gelatine and an inner shell containing cotton seed-oil. The object is again to protect the penicillin on its passage through the stomach. No reliable reports are yet available of the success or otherwise of treatment with these pills.

While administration of penicillin by mouth, by this or other methods, may become practicable in the future there is no immediate likelihood of a change in the present method of administration by injection, generally by continuous drip into muscular tissue.

Science for the Citizen—3

THE controversy about the desirability or not of arranging a moratorium for scientific research emerged from the columns of *The Listener* and took the air on March 2. If there had been a referee to assess the result of the bout (recorded) of verbal fisticuffs between Professor J. D. Bernal and Dr. C. E. M. Joad over the question "Should a halt be called to science?" the victory would probably have been given to Joad on debating points. His vast experience in Brains Trust technique enabled him to wriggle out of several tight factual corners and to parry with a flow of fast verbal jabs while preparing another attempt at a knock-out, which however never eventuated. On the whole it was a dull affair. It was a demonstration not so much of shadow-boxing, but of sparring in two quite different planes, for each man used a different evaluation of the same language and, no matter how attentively one listened, one could find no attempt by either speaker to make a glossary. Joad delivered one rabbit punch when he stated that his pupils came to him with a scientific knowledge that was a hundred years behind current research. Much of the speakers' limited time was spent in dialectical sparring and it is doubtful whether the time the B.B.C. devotes to science is well spent in this manner.

Several readers rang up about the "Rich and Strange" talks on plastics by "Rear Ranker". One was annoyed about the facetiousness of the scripts and puzzled by the speaker's pseudonym. With regard to the latter point, the B.B.C. informs us that it had some nautical origin, the speaker being a naval officer. But it is hard to see why he had to remain anonymous—or is that Silent Service policy? As for the facetiousness, humour helps at times—it is used most adeptly in "Your Questions Answered"—but we thought that "Rear Ranker" carried it too far, with expressions like "the bearded alchemists in skull-cap and nightie" coming in rather too frequently. Perhaps this chatty "Live Letter Box" technique has its ardent admirers but one wonders whether it is worth trying to convey serious information—and there was a good deal of information in these scripts—if it has to be pre-digested and regurgitated in such a pappy form.

The B.B.C. has published a booklet entitled "Britain Calling", which contains a number of complete English texts of talks broadcast as part of the Service in Kuoyu to China which was started in 1941. A high proportion of these talks are scientific. One feature of the service is a weekly review of current scientific periodicals that are on their way to China by microfilm: articles from *Nature*, *Discovery* and *Endeavour* are referred to in the talk printed in the booklet.

From the Scientific Films Committee of the Association of Scientific Workers, we have received a copy of a letter recently sent to the Board of Trade and the Ministry of Education on the subject of educational films. It urges the promotion of Legislation to implement the recommendations of the Film Council's report on the monopolistic tendencies in the film industry, and continues: "Further we are alarmed lest these tendencies to monopoly should spread into the field of educational film production. We suggest that, bearing in mind the needs raised by the Education Act and the shortage of fully trained teaching staffs, you take steps in collaboration with the Minister of Education to ensure an adequate independent supply of high quality educational films. During the war, the Government has gained valuable experience in the production, distribution and exhibition of films. Practical machinery for distribution exists, and the Government owns many projectors. We

recommend that all these be held available for education after the war."

The Mammalian Toilet

PROFESSOR F. Wood Jones, anatomy professor in Manchester University, addressed the Royal Institution on February 16 on the subject of the mammalian toilet. All animals in good health and in good surroundings keep themselves clean, he said; it is only when they are unwell or old that they allow themselves to get dirty. Animal toilet is particularly well developed in birds.

The teeth of most animals are kept wonderfully clean and free from debris by means of little horny-tipped processes developed along the inside of the cheek and tongue; these processes move up and down every time the jaw opens and shuts, acting like little tooth brushes—but they work up and down, not across. Man, who lacks these natural tooth brushes—although a new-born baby has the rudiments of them—has invented a tooth brush which works the wrong way round.

In the devices for keeping their fur clean mammals have the most striking adaptations in nature. To scratch themselves or keep their fur clean some animals roll on the ground, rub themselves against trees or use itching posts. Some can rub themselves with their horns or antlers, some use their tails as a switch, while others can twitch their skin. The first toilet depends on licking the fur with the tongue; the bear literally licks its young cub into shape in the first toilet. The tongues of many animals, such as the cat and lion, are covered with spines which are used by the animal for rasping meat from bones; but for every time they use it to get flesh from bones the tongue is used a hundred times for toilet purposes. The cat has almost invented a bath sponge by using its front paws to wash the parts of the body it cannot reach with its tongue. The Cape jumping hare has developed at the top of its hand a small swelling on the edge of which there is a perfect hair brush made of stiff bristles; it can brush its face with its own hair brush, and has thus gone a stage further than the cat.

Some animals have specalised dental hair-combs. The lemurs have specialised teeth which are elongated and appear similar to the teeth of a comb; the animal combs its hair by means of them. The lemurs have an instrument for keeping its "hair comb" clean; on the underside of the tongue is a thin layer of horny points used for that purpose. In the flying lemur each tooth is a minature comb.

Scratching is an art. There are hand-scratchers (monkeys and man) and foot-scratchers (e.g. cats and dogs). Human beings utilise different fingers to scratch different parts of the body. The first finger is generally used for scratching the head, and the little finger for inside the ear, while the middle finger does service for other parts. Animals also have specialised fingers. The lemur has a specialised toe with an outpointing nail for scratching.

Owing to this scratching, the hair does not lie in the same direction all over the animal; at certain places there are areas of hair reversal where the hair lies in a different way. The pattern of hair reversal varies from animal to animal. This reversal is the bane of taxidermists who always try to get the hair smooth all over.

There are four major reversals in all animals. The rhinal reversal, on the nose, is probably caused through animals licking their noses. The occipito-facial is the area where the hind foot scratches forward; a dog, for instance, scratches the ear and behind the head but avoids the eyes. The dorsi-lumbar reversal (manus reversal) arises through scratching with the forelimb. The ventral reversal is also due to forelimb scratching, or to licking.

Man is like no other animal; our hair tracks are specific. "Go home and scratch yourselves" Professor Wood Jones told his audience "and see if the hair doesn't lie in the way you are scratching". The hair on the arm is orientated towards the elbow, for the purpose—so Darwin suggested—of allowing rain to run off the elbow when the animal, man, was sitting huddled up in the rain. Human babies are born with whorls of hair on their heads and backs. The whorl on the head is more common on the left than right side. As more people part their hair on the left than on the right, is it that our ancestors have made the left-handed parting often enough for our babies to be born with a left-handed whorl? In other words, asked Professor Wood Jones, have men's actions in this instance had an hereditary value?

Personal Notes

PROFESSOR F. G. BAILY, emeritus professor of electrical engineering at the Heriot-Watt College, Edinburgh, died on February 23, aged 76.

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PROFESSOR F. Y. HENDERSON, reader in timber technology at the Imperial College of Science and Technology, succeeds MR. W. A. ROBERTSON as director of the Forest Products Research Laboratory, Princes Risborough, on April 1. Mr. Robertson has held this post since 1933.

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SIR JOHN BOYD ORR has announced his intention of resigning from the directorship of the Rowett Research Institute, which he has held since its foundation. He will continue as Professor of Agriculture in Aberdeen University and as head of the North of Scotland College of Agriculture. Sir John has been approached with a request to stand as a Parliamentary candidate for the Scottish Universities at the General Election, but recently stated that he had not reached a decision.

New Method of Measuring Crystals

A NEW method for crystal measurement which is likely to be greatly used in geodesy has been described by Dr. Lemmlein of the Moscow Academy of Sciences. The measurements are taken the following way. Duplicate stereomicrophotographs are made from the crystal; polar co-ordinates of the edges and faces of the three-dimensional image of the crystal are measured on a stereogoniometer. This instrument consists of a stereoscope affording a three-dimensional view of the crystal and a contact two-circle goniometer recording the positions by a special indicator brought to contact with the edges or faces of the three-dimensional crystal image. This method may be used successfully for crystallochemical analysis in studying microscopically minute crystals, crystals of unstable substances, and crystals which cannot be isolated from an enclosing medium. Imprints preserving the shapes of destroyed crystals can also be measured.

Physics and the Analyst

THE inaugural meeting of the Physical Methods Group of the Society of Public Analysts was held in London last month. Mr. R. C. Chirnside, F.R.I.C., delivered the first lecture to the Group, on the subject of "Physics and the Analyst".

Chemical Engineering at Cambridge

CAMBRIDGE University has accepted from the Shell group of oil companies an endowment of £435,000 for the establishment of a School of Chemical Engineering. In addition, a sum of £2500 a year is to be made available for scholarships. The output of qualified graduates from this department, it is proposed, should be about 30 a year.

Seaweed Research in Scotland

THE Scottish Seaweed Research Association has decided to go ahead with two years' research in West Scotland. On the advice of Mr. B. G. McLellan, F.R.I.C., M.I.Chem.E., director of the Association, the first work will be to investigate the volume of seaweed available, the period of growth, and the best and most economic methods of collection and delivery.

LETTER TO THE EDITOR

SIR,—A few months ago the Rt. Hon. Thomas Johnston said that he hoped that some research would soon be undertaken on the methods of control of midges, as this was of vital importance to the Scottish Tourist Industry.

I have been wondering if it is necessary to start this work from nothing, or if there are any reports available of work already done on the subject. I would be interested to know if any of your readers have knowledge of this difficult problem which would be useful and would inform me if it is published.

The midge problem is very widespread in western Scotland, and I feel that if science masters, particularly biologists, in the area were given some help and plan of guidance the collection of material would be speeded up and observations made in more variable habitats.

Yours etc., JOHN FLEMING.
Schoolhouse, Tighnabruaich, Argyll.

"Science in Peace" Conference

THERE was no lack of radical suggestions at the "Science in Peace" conference which the Association of Scientific Workers held in London at the Caxton Hall on February 17 to 18. Dr. M. Ruhemann, for instance, spoke of "doubling the output of coal per man-shift and halving the accident rate and the incidence of diseases" in mines—a target as ambitious as its achievement would be laudable—and urged the formation of a National Fuel Research Institution to deal with all fuel problems affecting the public; Dr. N. Levy envisaged a British plastics industry with an annual output of 1,000,000 tons a year (30 times the prewar output) and advocated the development of chemurgy—the production of chemicals from agricultural products—utilising crops from British farms. But flights of imagination were relatively few (to the chagrin of the reporters of the lay press); the speeches were kept at a practical ground level, probably because the scientists saw their science not as a thin and showy overlay but as something with strong roots in the social structure. The social aspect was stressed from the very first speech, in which Mr. G. D. N. Worswick, the economist familiar to radio listeners for the B.B.C. programme on "Full Employment" which he edited, discussed the future of British economy and stressed the point that full employment would create that scarcity of labour that gives the fullest opportunities to science and invention: if anyone has a vested interest in full employment it is the scientist, was one of Mr. Worswick's phrases.

The following speaker, Mr. Joe Scott, a member of the executive committee of the Amalgamated Engineering Union, agreed that unemployment and cheap labour operated against the full use of science. "If scientific methods cause unemployment one must not look with wonder on people who disapprove of the introduction of such methods", he said. "Such methods must not be allowed to lead to wage cutting and the displacement of skilled workmen". Mr. Scott wanted the unions to have full information about scientific and technical developments, and he foresaw an era of super-skilled workers with scientific and technical training. He did not think workers would continue to accept a world of machines about which they knew nothing, and the broad developments of science must be understood by trade unionists.

Dr. N. Levy, talking of the chemical industry, said that the output of synthetic nitrogen compounds had been enormously increased for war purposes, but the wartime nitrogen plants must not be allowed to fall into desuetude; their capacity could be taken up by an extended fertiliser programme.

Dr. M. Ruheman discussed the fuel and power industry. The failure to attack the problem of coal-winning he described as the source of all the misery in the mining industry; three British miners were needed to raise the same quantity of coal that one American miner deals with. But if the British scientist was at fault in this connection it was as a citizen and not as a scientist. With regard to underground gasification, Dr. Ruhemann said it could not solve all problems of British mining but it was important enough and offered such far-reaching possibilities that adequate facilities must be provided for extensive research and experimentation in this sphere.

The attitude of the British motor-car manufacturers towards research was censured by Dr. J. L. B. Cooper, who claimed that they spent only £20,000 a year as compared with the electrical industry which spent 6 times as much.

The first speaker at the Sunday morning session was Professor P. M. S. Blackett, president of the A.Sc.W. He began by saying that the main sanction for greatly increased support for science was because science was going to be useful. Following the lines of his recent British Association address (quoted in last month's DISCOVERY) he talked of the need for maintaining the balance between fundamental and applied research. With regard to fundamental science in the universities he thought that the organisation of it should be democratised, for the present system whereby university grants were administered by the University Grants Committee appointed by the Treasury made for bureaucracy. Fundamental science required guidance, but that guidance should come from the scientists themselves. He mentioned the need for a federation of scientific organisations which would be fully representative and could therefore speak on behalf of scientists to the Government.

Professor J. D. Bernal also spoke of the necessity of avoiding bureaucratic regimentation. Some control, by scientists, was needed to ensure a fair distribution of scientists, now in very short supply, between the various industries and inside each industry. In Britain we could not afford to duplicate scientific work by competitive and secret investigations. "It is not sufficient to provide research jobs and research organisations. The individual scientific worker requires conditions in which he can give of his best and this is not only—and even not mainly—a matter of wages and hours. It is a matter of securing for the scientist a place in industry commensurate with his importance to it. The scientific worker should be in a responsible position, able to use initiative and taking part in all discussions on policy," he commented.

Speaking about the training of scientists, Dr. Forbes Robertson said that, since science students should become widely-educated citizens, the inevitable specialisation should be delayed until the last year or two at the university. A wider range of subjects should be taken in the first two years, with emphasis on general principles and scientific method, rather than on excessive factual detail. A historical background would enable the student to assess better the part played by science at present and its probable development in the future.

At this stage the conference was addressed by two foreign scientists; the first was Dr. Marcel Mathieu, the second Professor A. Danilov, a Soviet delegate to the World Trades Union Conference.

Dr. S. Lilley dealt with the organisation and finance of science. He argued that Britain should spend £10 million a year on industrial research (against £3 million before the war), £600,000 on agricultural research (as against £200,000) and £4 million on medical research (as against £2 million). On fundamental research something like £2½ million should be spent: modern fundamental research was expensive, since it depends on electron microscopes and cyclotrons and can more and more rarely be carried on with pink string and sealing wax. He suggested the setting up of a National Research and Development Council, to survey our scientific needs and scientific resources and to plan in broad outline the scientific problems that have to be tackled and the strategy of tackling them. Of the taxation reliefs on industrial research expenditure, Dr. Lilley said, "We can give them support, but we have a right to insist that they shall be subject to conditions ensuring that the public shall get the benefit."

The final session dealt with "Science in Everyday Life"—science in terms of homes, hopes and happiness, as the chairman, Professor H. Levy, put it.

Mr. F. Le Gros Clark, discussing health, food and agriculture, expressed the opinion that one of the first measures after the war would be to revert to first dietetic principles and get back to *protein*, in which the world's population showed the most obvious deficiency. The cultivation of the soya bean and similar leguminous crops should be expanded and strains produced with a higher protein content; the extraction of protein from green leaves and the use of food yeast must be explored, and the preparation of palatable foods manufactured from such sources should be investigated. Secondly, we needed to develop the breeding of good dairy cows adapted to the purposes of every type of community, climate and fodder. Thirdly, we had only just begun to explore the potential harvest of the seas and inland waters, and measures should be taken to increase the food resources of fisheries and make them available. An intensive study of the problems of food technology and food distribution and transport was urgent.

The possibilities of prefabrication were touched on by Mr. Harold Rose, who pleaded for prefabrication to be dissociated from the word "temporary". Prefabrication was no more than the application of factory methods to building construction, so that the greater part of the normal site operations were carried out in the factory. To illustrate the economy thus made possible he cited the fact that at least six tons of water are used in the construction of a normal brick house, all of which has to dry out before habitation; prefabrication meant dry assembly and immediate occupation. There was need for a large-scale programme of building research to be established by the Government, universities and the building industry. Building science should be part of the general curriculum of technical schools.

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